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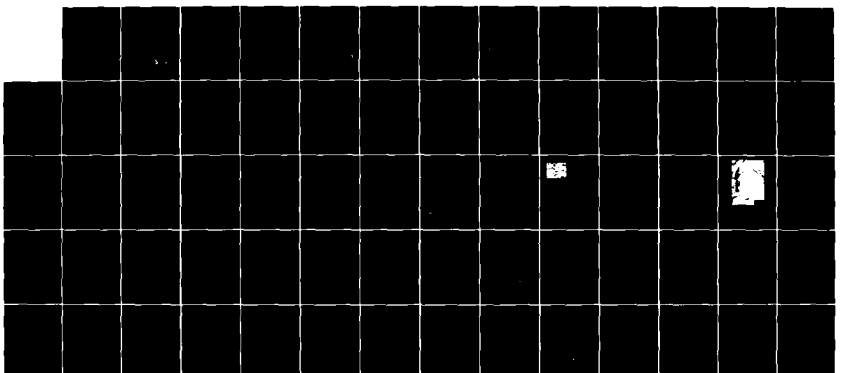

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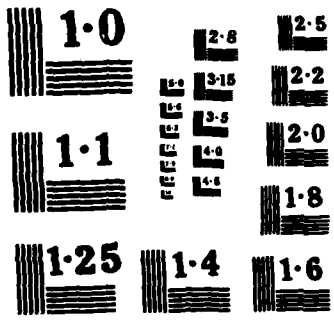
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ESN 38-9

September 1984

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1. REPORT NUMBER 38-9	2. GOVT ACCESSION NO. AD-A145	3. RECIPIENT'S CATALOG NUMBER 683
4. TITLE (and Subtitle) EUROPEAN SCIENTIFIC NOTES nlo 38-9		5. TYPE OF REPORT & PERIOD COVERED Monthly September
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Larry E. Shaffer, editor		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Office of Naval Research Branch Office London Box 39 FPO NY 09510		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE September 1984
		13. NUMBER OF PAGES 58
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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EUROPEAN SCIENTIFIC NOTES
OFFICE OF NAVAL RESEARCH
LONDON

Commanding Officer ..... CAPT M.A. Howard, USN
Scientific Director ..... James W. Daniel
Editor ..... Larry E. Shaffer

September 1984
Volume 38
Number 9

BEHAVIORAL SCIENCES

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BEHAVIORAL SCIENCES

THE PSYCHOLOGY OF CATASTROPHIC ERRORS

by Richard E. Snow. Dr. Snow is the Liaison Scientist for Psychology in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until September 1985 from Stanford University, where he is Professor of Education and Psychology.

Why did Captain Nolan misdirect the Light Brigade to its destruction in a valley during the Battle of Balaclava in 1854, even though he had a panoramic view of the battlefield?

Why did Admiral Tryon order two parallel lines of the 1895 British Mediterranean Fleet to turn inwards 180 degrees when the lines were only 1200 yards apart and the leading ships each required a turning circle of 800 yards, causing a collision that cost 365 lives?

Why, in 1975, did Motorman Newson drive his London tube train at a steady 35 mph into a blind tunnel at Moorgate station, killing 42 and injuring 74 passengers?

Why did Captain Van Zanten start the takeoff of his KLM 747 after receiving airways clearance but before receiving takeoff clearance, thus colliding with an oncoming Pan Am 747 in the Tenerife disaster that claimed the lives of 577 people in 1977?

Professor James Reason of the Department of Psychology, University of Manchester, UK, uses these and many other similar examples to examine the little slips that cause big disasters (Reason, 1984; see also Reason and Mycielska, 1982). He argues that the horrendous consequences of such accidents distort our perception of the events that led up to them and thus demand explanations that assume irrationality--official inquiries judged Captain Nolan crazy, Admiral Tryon drunk or crazy, and Motorman Newson a suicide, for example. It is more likely that catastrophic errors are indistinguishable psychologically from the many familiar and ordinary, "absentminded" slips and lapses of everyday life, except in their consequences.

Absentminded errors appear to be just what their name implies--errors committed while the actor is not investing conscious attentional control in the act. Such errors are:

1. Characteristic of highly skilled or habitual, well-practiced, and recently or frequently executed activities, i.e., where performance is largely automatic.

2. Committed in familiar and relatively unchanging surroundings such as kitchens, bedrooms, bathrooms, and offices or other regular work spaces.

3. Most likely associated with some degree of diversion of attention to internal or external preoccupations or distractions.

4. Often the result of habit intrusions, where the diversion is from an intended sequence of acts to some other familiar, habitual sequence of acts that would otherwise be appropriate in that environment.

5. If not directly due to habit intrusion, due then to habit interaction of one of two other, similar sorts. There are place-losing errors, where a routine check on the progress of an automatic sequence causes interruption, subsequent loss of place, and an incorrect result. There are also interference errors, where the parts of two routines active at the same time are blended, reversed, or otherwise transposed.

Reason goes on to show that intrusion, place-losing, and interference errors are similar to various kinds of slips of the tongue. He likens such errors to spoonerisms, noting that blending slips such as *absotively* (from *absolutely* and *positively*), or transposition slips such as *many thinkle peop so* (instead of *many people think so*) are not uncommon. But attention controls deeper in the human cognitive system do seem to keep most people from spoonerizing phrases such as *pheasant plucking* that would give socially unacceptable or embarrassing results.

Reason's research leads to reanalyses of many disastrous accidents, as well as of the many spoonerisms and other verbal slips common in psycholinguistic data. He finds plausible bases for inferring that most such errors are quite ordinary. The action routines that lead to them tend to be more conservative than the intended action, in the situations where they occur. The more a particular action routine is used in a particular person's experience and the more it achieves its desired result, the more it is likely to appear uninvited as a slip of habit. With respect to habit intrusions, which are the main source of such errors, Reason (1984, p 184) thus formulates a Law of Errors:

"Whenever our thoughts, words, or deeds depart from their planned course, they will tend to do so in the direction of producing something that is more familiar, more expected, and more in keeping

with our existing knowledge structures and immediate surroundings, than that which was actually intended."

His work also combines with that of Professor Donald Broadbent of Oxford University to suggest that individuals differ widely in their error proneness and that this is a fairly enduring and general characteristic of persons. It thus appears associated with some central control process rather than particular parts of the cognitive system. There is also some evidence that current error proneness relates to accident history and to vulnerability to stress.

Reason proposes a three-tiered model of control in the cognitive system. At the highest level is the conscious Intention System concerned with goal-setting, strategy-choosing, and trouble-shooting unexpected events. At the lowest level is the largely nonconscious collection of schemata that guide automatic processes of perception, speech, thought, and action. Schemata can be run off under conscious control but also automatically in response to external conditions. Between them is an Attention Control System. Conscious concerns make the largest demands on the attentional resources and these vary continuously. All activities, no matter how automatic, require some attention resources, but habitual activities demand less. Absentminded errors occur when too much attention is directed away from the task at hand, relative to what is needed for that task at that moment. Automatic processes require more attention at nodal or branching points, and to keep highly active schemata in check. Errors thus occur when there is too little attention devoted to suppressing unwanted schemata or branches; the needed attention is occupied elsewhere.

It is true, of course, that drunkenness or pathological disturbance can promote distraction and the misdirection of attentional resources and can thus lead to error in the same way that the many sources of "normal" distraction lead to error. The effects of anxiety and fear can be understood in the same way (see next article). While there is not sufficient evidence to reconstruct the cases of Captain Nolan or Admiral Tryon in this light, we do know more about Motorman Newson and Captain Van Zanten.

Newson had traveled that same route 228 times in the previous 2 weeks, and twice earlier on his last day. But on the two earlier trips the lights were on in Moorgate tunnel; they were off on the third trip, as they usually are in all the other tunnels on the line. He was also carrying money to buy a special present for his daughter after work. Reason's theory plausibly supposes that he was distracted by this and lulled into a place-losing error some stations back. The absence of lights at Moorgate preserved a habit intrusion until panic froze it into place at the last moment.

Van Zanten had spent 1500 hours in a flight simulator in the years preceding Tenerife; he was principally a flight trainer and had not had a line flight for 12 weeks. In the simulator, airways clearance and takeoff clearance are given simultaneously! In the stress of having been diverted to an unscheduled airfield, Reason suggests that he reverted to the habits of the simulator.

Following Reason and the philosopher John Watkins, whom he cites, we need a "principle of imperfect rationality" which requires us to search for rational explanations of accidents, however imperfect, rather than relying too quickly on assumptions of irrationality. We also need means, both psychological and technological, to reduce the likelihood, or the effects, or both, of ordinary human errors--which also means we need to understand them better.

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6/22/84

THE PSYCHOLOGY OF DANGEROUS JOBS

by Richard E. Snow.

Danger brings out courage. It also produces states of high anxiety and fear in individuals, which in turn can reduce performance effectiveness. In groups, fear can become contagious, leading to panic--which in turn multiplies the danger and reduces performance still further. Yet effective performance is especially critical in such situations because dangerous environments generally require active, correct responses for individuals to survive, much less to succeed.

Many thousands of anecdotal and other records exist describing the psychological and physiological concomitants of danger and their effects on

human performance. Much of this evidence comes from self-reports, observations, and interviews collected during or after natural disasters, massive accidents, or dangerous military operations. It has been known since early history, for example, that fear can be widespread among soldiers in the heat of battle, and it can be made worse by poor communications and loneliness; after the Battle of Gettysburg, and in many later wartime engagements, it was found that large proportions of soldiers failed actually to fire their weapons. Also, many kinds of tactical, navigational, and communications mistakes can multiply with danger; the individual's recognition of these can lead to hesitancy. In the extreme, individuals can become paralyzed with fear.

But much of the evidence accumulated from these sources, though useful, is circumstantial, correlational, and descriptive. Because of definitional ambiguities, various methodological inadequacies, and ethical limitations, there have been few definitive experiments on courage, anxiety, and fear in dangerous situations, and their performance effects. There are a multitude of individual and social factors to untangle. And it has been difficult to sort out the various possible effects on human performance and to test particular causal linkages.

Alan Baddeley and his coworkers at the Medical Research Council-Applied Psychology Unit, Cambridge, England, have carried on a research program in this field for many years. They have recently contributed a review of the older literature (see Idzikowski and Baddeley, 1983a) and several new experiments (Lewis and Baddeley, 1981; Logie and Baddeley, 1983; Idzikowski and Baddeley, 1983b). The most important of these concern cognitive performance during deep-sea dives; the aim was to evaluate the effects of breathing mixtures as well as anxiety on performance. Baddeley himself is a diver, so he brings personal insight as well as experimental rigor to the research.

A selective summary can be extracted from the Idzikowski-Baddeley literature review; it appears in Table 1 (citations to particular studies are not given, but may be obtained from the original source). The table is organized to group studies according to person-situation examined; studies of ground combat situations are given first, followed by flying, diving, and parachuting situations, and then a small group of miscellaneous studies.

The review gives many clues, but much of the research is limited. Self-report measures taken after a danger has passed may be limited by the variabilities of human memory after such experiences; verbal report can also be distorted by insufficient verbal facility on the part of the reporter, the need to limit personal disclosure, and a number of other factors. State-rating scales administered during time of danger or its anticipation may be responded to superficially or hastily and may suffer from unreliability. On the other hand, physiological and biochemical measures, while less obtrusive, do not necessarily reflect anxiety alone or directly; different measures may be influenced by a host of other factors differentially and may thus not correlate with one another or with the subjective experience of anxiety or fear. Also, unfortunately, many studies have not included adequate measures of cognitive performance. The best evidence would come from studies that showed correlation among subjective reports and physiological or biochemical measures and between them and some physical scale of actual danger--such as depth of dive, percent of actual aircraft lost in battle, distance to target--and that also provided a performance profile across the major categories of relevant cognitive and motor tasks. Such studies are extremely difficult to obtain.

Nonetheless, the patchwork of evidence in Table 1 does support some conclusions, especially when combined with extant theoretical views of arousal, anxiety, and performance.

1. One can distinguish between state and trait anxiety. State anxiety is a transitory emotional condition characterized by feelings of tension, apprehension, and heightened autonomic nervous activity. Trait anxiety represents individual differences in a stable predisposition or proneness toward such feelings. Fear is a high anxiety state, usually where the eliciting conditions are known to the subject. The research in Table 1 reflects some effects of state anxiety (or fear) but does not examine trait anxiety or state-trait interactions.

2. The situations studied to date can be expected to have elicited quite different degrees of anxiety or fear and so do not sum to simple conclusions. But the evidence does support the view that performance decrement is to be expected under conditions of high anxiety or fear.

3. The evidence for impairment is clearest for tasks requiring motor coordination or manual dexterity, possibly because anxiety is often accompanied by

Table 1

A Summary of Findings on Anxiety, Fear, and Human Performance in Dangerous Situations (Based on Idzikowski and Baddeley, 1983)

Senior Author	Year	Persons & Situation Studied	State Measures	Performance Measures	Findings-Implications
Marshall	1947	WW II battles	Psychatric interviews on fear	Weapon firing	Fear widespread on battlefield; often only 15-25% of soldiers fired their weapons.
Bourne	1967	Soldiers in Viet Nam	Biochemical measures	--	Testosterone secretion decreased in battle situations.
Berkun	1962	Ground simulated combat exercise	Self-report & biochemical measures	Radio repair Form completion task	Although measures indicated stress and anxiety, performance decrements occurred only in artillery barrage situation, not in forest fire or radioactive fallout situations. Clear deterioration of form completion.
Grinker	1945	WW II flyers	--	Observations	Mild anxiety states show motor signs but no interference in performance. Tremor, jitters, severe tension over target area which may progress to mistakes. Severe anxiety producing regression, confusion, mutism, and stupor are not seen in fliers as they are in ground soldiers.
Reid	1945	WW II bomber navigators	--	Navigation errors	Errors increased over enemy coast, and again approaching target, declined returning across coast.
Walker	1965	WW II bomb system control	Combat severity as percent of aircraft lost	Errors in combat vs. errors in training	Substantial control performance deficits occur as combat situation becomes more dangerous.
Lewis	1967	Bombing mission	Physiological measures	--	Pilot heart rate increased on takeoff, again during raid, then decreased on return to base.
Austin	1969	Flying in Viet Nam	Biochemical measures	--	Phospholipid secretion increased in battle flying.
Baddeley Davis	1966 1967 1968 1972	Divers	Conditions & depth of dive	Manual dexterity tasks	Dexterity is increasingly impaired with increasing danger and depth, but especially where danger is defined as poor vs. excellent diving conditions or pressure chamber vs. open sea diving without apparent bottom.
Mears	1980	Divers	Depth of dive self-report & heart rate	Manual dexterity tasks	Dexterity is increasingly impaired with increasing depth.

Table 1 (Cont'd)

Senior Author	Year	Persons & Situation Studied	State Measures	Performance Measures	Findings-Implications
Radloff	1968	Navy divers in sealab	--	Interpersonal relations observed	Relations between divers better in underwater habitat than on surface.
Weltman	1966	Open sea diving	Heart rate	Dual task with light detection secondary	Novice performance on secondary task deteriorated substantially in dive compared to controls. Heart rate and reported anxiety increased in dive.
Weltman	1971	Pressure chamber diving	Self-reported anxiety		
Hammerton	1969	Military parachuting	--	Tracking task	Tracking performance most impaired in inexperienced jumpers, least impaired in trained and experienced jumpers.
Basowitz Halse	1955 1978	Military parachuting	Self-report	--	Increases in subjectively felt anxiety preceding and during jumps.
Simonov	1977	Parachutists on board aircraft	Physiological measures	Visual recognition of numbers	Marked deterioration of performance under stress.
Basowitz	1955	Men in parachute training	--	Tachistoscopic figure reproduction and digit span memory	Poorer performance relative to controls.
Fenz Fenz Grierson	1964 1968 1975	Sports parachuting	Physiological measures & thematic apperception test	Word-association and memory tasks, auditory threshold	Parachutists react strongly to parachute-related words but experienced jumpers not as reactive. Novices also react to anxiety-related words. Auditory threshold higher and more anxiety words misperceived for novices on day of jump; they also show general memory deficits. Many fear responses to thematic apperception pictures on day of jump despite denial of fear. Experience and competence in jumping leads to reduction of fear responses.
Epstein Grierson	1965 1975	Sports parachuting	Self-report	--	Experienced jumpers reported maximum avoidance night before jump, whereas novice jumpers reported avoidance closer to jump. Experienced jumpers reported pleasure and little fear.
Fenz Shane Grierson Stromme	1967 1968 1975 1978	Sports parachuting	Physiological measures	--	Increases preceding and during jump in heart rate, respiration, absolute skin conductance.

Table 1 (Cont'd)

Senior Author	Year	Persons & Situation Studied	State Measures	Performance Measures	Findings-Implications
Bloom Hansem Weitzman Eide Basowitz	1962 1978 1978 1978 1955	Sports parachuting	Biochemical measures	--	Increases preceding and during jump in: (1) adrenaline and noradrenalin secretion, (2) growth hormone secretion, (3) blood glucose levels, (4) hippuricacid excretion and blood glutathione.
Noel	1976	Sports parachuting	Biochemical measures	--	Increases after jump in plasma prolactin, growth hormone, and thyrotropin secretion.
Davidson	1978	Sports parachuting	Biochemical measures	--	Decreases after jump in testosterone secretion.
Epstein	1965	Sports parachuting	Self-report & physiological measures	--	Experienced jumpers show moderate arousal increase before entering aircraft. Experienced but incompetent jumpers show subjective and physiological responses similar to novices and also if probability of accidents is seen to increase; experience reduces subjective and physiological responses.
Andersson	1976	Flood disaster	Questionnaires & interviews on stress & coping	Small business recovery	Curvilinear relation between perceived stress and business recovery; low to moderate stress led to improved performance.
Mende	1966	Mine disaster	Fear observed	Leadership emergence observed	Person who emerged as group leader had shown greatest fear under initial strain.
Bergstrom	1970	Impending electric shock	--	Tracking tasks	Many instances of impairment, but not clear whether in dexterity or sensory-perceptual processes.

disruption of muscle tone. It is also possible that attentional deficits caused by anxiety interfere with motor execution.

4. The evidence is less clear for cognitive tasks. Some studies show that cognitive performance decrements can be minimal even when subjective and physiological indices confirm that an individual is anxious or frightened. It could be that some kinds of tasks show more decrement than others, perhaps because of their heavier attentional demands, or that performance on some tasks or in some situations is readily adapted to situational demands, or that persons differ in these respects; marked performance decrement may occur mainly where state and trait anxiety combine but, as noted above, trait anxiety has not been included in most of the research.

5. Theory suggests that arousal acts by narrowing attention and so should adversely affect performance on peripheral tasks more than central tasks in multiple-task environments. Most past research has concentrated only on central tasks, however.

As noted above, two of Baddeley's latest studies provide more intensive examinations of the cognitive performance of divers. The first of these (Lewis and Baddeley, 1981) compared dives to 300, 420, and 540 meters of seawater (msw) in an oxyhelium atmosphere; the dives varied from 18 to 26 days in length in a laboratory chamber. From previous work it is known that a diver breathing pure oxygen cannot avoid oxygen poisoning beyond a depth of 15 to 20 msw. For a diver breathing air, the maximum practicable depth is about 60 msw, beyond which nitrogen narcosis will cause serious deterioration of performance. In contrast, use of oxyhelium mixtures permits dives to 600 msw without physical harm. However, it has not been clear that nervous disorder and cognitive performance impairment can be fully avoided with this mixture at such depths. Some studies show impairment on some tasks, some show no impairment on others, and there is the possibility that anxiety or mood disturbance in general can affect sleep patterns and fatigue as well as task performance.

In the new work, Lewis and Baddeley included mood and sleep questionnaires as well as performance tests of numerical addition, paired associates memory, grammatical reasoning, Stroop cognitive interference, color matching, number comparison, knowledge verification, digit span, and visual search. The test battery thus covered a wide spectrum of human abilities. It was administered on the surface, at depth, and after decompression. Most scoring emphasized speed of performance, but errors were also noted.

Results showed marked impairment of cognitive performance at depths exceeding 300 msw on all but two tests; grammatical reasoning showed no impairment, and paired associates memory performance actually appeared to be improved at depth. Thus the effects of breathing oxyhelium at pressure are somewhat selective rather than general; rote learning and simple verbal reasoning appear unaffected, whereas negative effects on numerical and visual-perceptual abilities, knowledge retrieval, memory span, and susceptibility to interference can be substantial. It is suggested that ability profiles might be used to show the effects of different kinds of stressors in further research.

The results also suggested that performance decrements were not associated with sleep disruption nor with changes in moods related to anxiety. The small number of subjects and the artificial, controlled environment, however, may limit the generalizability of these latter results.

The second experiment (Logie and Baddeley, 1983) tested a new gas called Trimex (a mixture of helium, oxygen, and nitrogen), which allows substantial reduction in compression time requirements. Again mood and sleep disturbance questionnaires were used along with tests of numerical addition, grammatical reasoning, color matching, number comparison, knowledge verification, and visual search. Administration of measures took place three times before the dive, five times at different depths during compression, six times during decompression, and twice after the dive was completed. Depths used ranged in intervals from 2 to 660 msw.

Blanket impairment of performance was found on all tests at 660 msw; it was less marked but appreciable at 540 msw. At 420 msw, performance was below that of surface performance but better at this depth after 21 hours of compression than it had been at this depth during initial compression. This result suggests some adaptation. At 300 msw, performance was slightly affected on all tests except visual search and color matching. Trimex appears to be associated with greater cognitive impairment than is oxyhelium, at least at the more extreme depths; it thus may not provide the neat solution, as previously expected.

Again, mood and sleep quality varied substantially with depth but seemed unrelated to performance decrements. Again, however, anxiety states probably differ significantly between chamber and open-sea conditions.

Idzikowski and Baddeley (1983b) have also contributed a study of anxiety and performance decrement among inexperienced speakers in a public colloquium situation; although public speaking is not usually considered physically dangerous, it is often regarded as psychologically dangerous. The subjects were new postdoctoral fellows giving their introductory speech to the Applied Psychology Unit-Cambridge or to its annual symposium. Ambulatory heart rate, subjective ratings covering alertness and tranquillity, and performance on digit span, logical reasoning, cognitive interference, verbal fluency,

and motor tasks were measured during practice, at baseline, and during or just before the speech.

Subjects were found to be significantly more tense, excited, and troubled just before the talk; thus apprehension was high, tranquility was depressed. Heart rate showed substantial increase over baseline just before and during the talk; peak heart rate occurred at the beginning of the talk. Substantial individual differences among speakers were noted, however. There were also significant performance decrements on two cognitive tasks: digit span and verbal fluency. But the other cognitive tasks showed no decrements, and all performance differences were modest. Thus the results suggest a resistance of performance to disruption despite anxiety.

The ability to cope despite moderate levels of fear is clearly adaptive for human beings. The point at which increasing levels of fear will substantially disrupt performance will be extremely difficult to determine. It will clearly differ for different persons and for different situations, as well as for different tasks. Baddeley's work suggests that a standardized profile of cognitive tasks and self-report state and trait anxiety scales would be extremely useful for further work. So also would be some sort of taxonomy of dangerous situations; given that much of the evidence will continue to arise unpredictably from natural situations, such a reference standard would be an aid to interpreting the particular conditions of each study in common terms. Military and sports parachuting and diving appear to be the primary situations available for study with rigorous methods. These may thus be the best foci for concentrated reseach aimed at developing comparative standards.

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BIOLOGICAL SCIENCES

EUROPEAN-COMMUNITY ACTION PROGRAM FOR BIOTECHNOLOGY

by Thomas C. Rozzell. Dr. Rozzell is the Liaison Scientist for Biological Sciences in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on reassignment until August 1985 from the Office of Naval Research, Arlington, VA, where he is Program Manager for Cellular Biosystems.

The European Community (EC) recently presented proposals for a 5-year, 200 million ECU action program for research and development projects in biotechnology (1 European Currency Unit equals approximately $0.8223). This action grows out the EC's realization that it is lagging behind much of the world in this burgeoning new technology area.

The progress of the life sciences has made an increasing volume of molecules and cells, both of vegetable and animal origin, available for use in agriculture, food processing, the chemical and pharmaceutical industries, the production of biomass energy, and the recovery of waste. The economic stakes are enormous. About 40 percent of manufactured goods are biological in origin. It is estimated that by the year 2000 the world market for biotechnology could exceed $100 billion. The EC now realizes that it must be able to compete effectively with the major international powers for this market. In so doing, the Community will be in a better position to attain a number of political objectives. These include assisting the Third World to become self-sufficient in food and thus reduce public expenditure on agriculture and health care. A number of areas within biotechnology have not been explored by EC member countries and are just beginning to be studied by other countries. The time is now ripe for the EC. I recently wrote about Ireland and its push into this area (*ESN* 38-8:457 [1984]).

All of the major industrial powers of the world are already moving toward a "biosociety" highly controlled by electronics and computers. American expenditure in biotechnology research is twice that of the entire EC--although it's only half again that of the EC when all fields of research are considered--and industrial uses are even further ahead. Japan has also begun an ambitious R&D program in biotechnology which, if past

trends are followed, will seriously challenge the US program in a few years. In the meantime, Europe continues to lose large numbers of biological scientists and engineers through immigration--mostly to the US. In addition, the EC is increasingly dependent on imports of both biotechnology products and patents. Some of the major reasons for this rather sad state of affairs are the disparate nature of national research and development efforts, the compartmentalization of the Community market by differing national standards and regulations, and a relative shortage of adequately trained scientists.

The EC's proposals are designed to combat these shortcomings in an effort to create a "critical mass" for development on a continental scale. The 5-year program outlined in the proposals will cost about 200 million ECU. It will consist of research and development projects and efforts to create a favorable climate for progress in biotechnology. The main features of the program are outlined below.

Research and Training in Basic Technologies

This will be a research and training program aimed at the intermediate stage between pure and applied research. Currently, many firms are reluctant to invest funds in research with long lead times. The EC has already started a 5-year program (1982-86) in seven fields of biomolecular engineering, ranging from the study of enzymes and genes to methods of estimating risks. Research institutes have shared the cost of more than 100 projects that have helped create research centers and disseminate information in key sectors of biotechnology. But this program is too small to systematically solve the problems that prevent the application of genetics, biochemistry, and microbiology to agriculture and industry. Efforts will be made to upgrade training programs and to encourage researchers to move among the best European laboratories. Being multidisciplinary, biotechnology is rarely taught as a subject area as such. New educational techniques will be devised to disseminate information to students and working scientists. Information banks will be set up; data banks and other computer-related techniques will be developed.

Specific Research on Health and Disease

Certain areas--such as health (the prevention and rapid treatment of certain endemic diseases), agriculture, and advanced chemicals--will be given special emphasis to improve European competitiveness, reduce trade imbalances, and lower the costs of production and raw materials.

Agricultural and Industrial Changes

With the realization that there is a growing interdependence of agriculture and industry that brings with it increasing exchanges of services and products, certain changes will be made to manage these areas more effectively. Efforts will also be made to provide better access to raw materials of vegetable origin. It is envisioned that the competitive edge of European industry can be sharpened by changes in common agricultural policies for products such as sugar and starch. Hopefully, this will apply to new products derived from genetic engineering techniques.

Policies for Standards and Regulations

At present, there are as many different national standards for such things as pharmaceuticals as there are members of the EC. To achieve reasonable profits and compete effectively with the rest of the world, it will be necessary to eliminate major differences that hamper investment incentives. The proposal will not attempt to replace national standards with Community standards, which is already happening in other sectors. Rather, a framework will be developed for Community cooperation on the creation of common standards that will actually encourage the application of biotechnologies. Such a framework will attempt to ensure that safety and health standards are maintained uniformly in order to preserve and heighten consumer confidence in the bio-industries.

Policy for Intellectual Property Rights

This program will attempt to solve problems associated with the patent and copyright laws of the member countries. The national laws in this area now differ widely. There is a copyright convention, but it has not been ratified by all member states of the EC. No decision has been made about whether it is possible to patent a microorganism or genetically engineered cell line. In fact, this is a considerable problem in the US as well, as evidenced by a recent article in *Science* (Adler, 1984).

With this program the EC hopes to extend its existing program of studies and dialogues, involving both labor and management, on subjects such as worker participation in ways of introducing new technologies into their industries. The Commission of the European Communities plans new efforts to raise public awareness and retrain technicians and specialists who may have been displaced by new technologies and mechanization. The

success of this program will be a major deciding factor in the EC's worldwide competitiveness, its share in the world market, and the number of scientific and technical jobs available to its citizens.

Reference
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NEW REPORTS ASSESS BEM RESEARCH IN FRANCE AND GERMANY

by Thomas C. Rozzell.

The Office of Naval Research, London, has recently published two technical reports dealing with bioelectromagnetics (BEM). Report R-8-84 is *"Bioelectromagnetics Research in France--An Assessment"*; report R-9-84 is *Bioelectromagnetics Research in Germany: An Assessment*. The reports review the activities of the principal researchers in these two countries over the past few years, discuss the quality of the research, and attempt to show what the future picture will be.

Over the past decade, France played a major research role in BEM. While the total French program was moderate compared with those of other countries, the contributions it made were highly significant and affected almost every area of the field. A wide variety of cellular and membrane work was carried out in Paris at Institute Curie and Centre National de la Recherche Scientifique (CNRS); nonperturbing temperature probes were developed in Toulouse; instruments and exposure systems were designed and built and electric properties of materials studied at CNRS; animal behavior and electroencephalogram changes were investigated at Toulon; and hyperthermia methods were developed at Lyon, Lille, and Toulouse--just to name a few accomplishments of the French research program.

Much of the support for the research came from the military via the Direction des Études et de Recherche Technique (DRET) and CNRS. With the exception of a few scattered projects, all of the bioelectromagnetics research was funded by these two agencies. Until approximately 2 years ago, the program at DRET was managed by Colonel G. Plurien, a navy physician who fought to build the program and defended it at the highest level of the military establishment. He was replaced in normal rotation by a manager who has given BEM research such a low priority that all funding will cease by the end of this fiscal year.

According to several of the current and past researchers who were interviewed in preparing the report, CNRS, observing the decision of DRET, decided to do likewise. Instead of filling in the support void, they apparently decided not to be a loner in support of this area of research. In all fairness, part of the rationale for the decisions of these two agencies lies in the general economic situation and the demand for R&D funds from new scientific and technological areas such as biotechnology and microelectronics. Thus, in the reordering of priorities it was apparently decided that France could afford to "piggyback" onto other countries in this research area and thus free funds for other R&D that doesn't lend itself so readily to dependence on outside sources.

Report R-8-84 looks at some of the recently completed research, which because of the decisions discussed above is being terminated, and at some research carried out over the last 3 to 5 years. The latter helps to demonstrate the breadth and scope of the research program as it was and the level of competence of the investigators.

The French have not put much effort into the type of clinical applications that the Italians and Germans are currently pushing--magnetotherapy. There has been, and still is, a considerable amount of work involving hyperthermia devices for cancer treatment. The support for hyperthermia research often comes from the cancer research agencies, and therefore is a little different from the usual BEM support.

Since the major governmental supporters of BEM research in France have decided to redirect funds for this research into new, emerging technologies, they must rely on the research results of other countries to support any new standards or develop biomedical applications. The BEM researchers, who have been very active over the past decade, are now beginning to channel their expertise into other areas of science and engineering. Unless support is found immediately in industry or in other countries, France will no longer be an actor on the BEM stage, merely a spectator in the audience.

Report R-9-84 examines West Germany's BEM research, which is centered

around two major laboratories: The Max-Planck-Institut für Festkörperforschung in Stuttgart and Gesellschaft für Strahlen- und Umweltforschung in Neuherberg, just outside of Munich. While there is a considerable amount of research in other parts of Germany, these two laboratories are by far the major centers.

For several years a number of researchers have been looking for the frequency-dependent effects predicted by Fröhlich and suggested by the experiments of Webb in the US and by a group Soviet workers led by Smolyanskaya and Vilenskaya. Fröhlich suggested that critical oscillations exist in macromolecules that determine the activity and function of the organism. It is believed that the frequencies of these oscillations lie roughly between 100 and 1000 Ghz. It is reasonable to conjecture that functional activities occurring at the macromolecular level depend on critical, and perhaps matching, oscillations being present at the right place and time for a given reaction to occur. Such oscillations might be finely tuned and "metastable," in which case small inputs of energy to one or both halves could cause disruption in the progress of the function or reaction. Fröhlich and others actually postulate that there is a type of threshold or limit cycle in metabolic excitation of large-amplitude vibrations.

It appears that the BEM workers in Germany decided that this was an important enough area to devote considerable effort to it. This they have done, and for the last few years they have produced some of the most interesting and technically precise research to be reported anywhere in the world. Since some of the early work suggesting nonthermal, resonant phenomena was done at millimeter-wave frequencies (above 35 GHz), the Germans apparently decided to work in this range. Thus, almost all of their research has been conducted using millimeter waves. Report R-9-84 highlights some of the key German research carried out on millimeter-wave effects during the past 2 to 4 years, and other BEM research relating to biological effects as well as diagnostic and therapeutic applications.

Further details are available in reports R-8-84 and R-9-84, which you can order by filling out the mailer inside the back cover of this issue.

THE CIBA FOUNDATION--PROMOTING INTERNATIONAL COOPERATION IN MEDICAL AND CHEMICAL RESEARCH

by Thomas C. Rozzell.

The Ciba Foundation is a scientific and educational charity established in 1947 by CIBA Limited--now CIBA-GEIGY Ltd.--of Basel, Switzerland. To distinguish between the foundation and the founder company, the foundation is referred to as "Ciba" rather than "CIBA." The name CIBA derives from the initial title of the company--Gesellschaft für Chemische Industrie in Basel. Located at 41 Portland Place, the Foundation operates independently in London under English trust law.

The Ciba Foundation was established in London because the law governing charities based in the United Kingdom ensures complete independence; because English had become the international language of science; and because London has good communications with most other countries. The founding company, which merged with J.R. Geigy SA in 1970 to form CIBA-GEIGY Ltd., supports the foundation financially but cannot determine its policies. Five trustees, acting through the Executive Council of up to nine members, are responsible for the policies of the foundation. The trustees and the members of the Executive Council serve on a voluntary basis and are drawn from well-known and respected members of science, medicine, law, and community affairs. The day-to-day activities of the Ciba Foundation are the responsibility of the director, currently Dr. David C. Evered, who is responsible for implementing policies and supervising all the activities of the foundation.

Other members of the senior staff include: Dr. Ruth Porter, Deputy Director; Mr. Geoffrey B. Heckford, Assistant Director for Finance and Administration; Dr. Jonathan H.A. Nugent, Senior Scientific Officer; Ms. Maeve O'Connor, Senior Editor; and Dr. Chris Langley, Information Officer and Librarian.

The Ciba Foundation seeks to stimulate and contribute to science by holding several kinds of symposia, meetings, and study groups at its location in London. The foundation's activities, which Porter described to me, are discussed below.

Scientific Meetings and Scientific Books

The foundation makes its contribution to research by holding its own

symposia, study groups, and meetings as well as by lending its facilities to other organizations for meetings. The Ciba Foundation has held over 800 scientific meetings of its own and has brought together approximately 25,000 scientists from more than 70 countries. The foundation holds four specific types of meetings, which are described below.

Symposia. These are 2- or 3-day meetings held about eight times per year on a wide range of topics that are, in the eyes of the staff, ready for intensive discussion by a small international group of researchers. Attendance is limited to approximately 25 people, and admission is strictly by invitation. Thus far, the Ciba Foundation has held over 225 such symposia. The proceedings of the symposia are edited by the foundation staff and published in hard cover as the Ciba Foundation Symposium series by Pitman. These books, with their stimulating discussion sections, are a unique source of information on biological and medical research. The books not only provide a permanent record of the papers presented and the discussions for the participants, but also offer topical research reviews for a much wider audience. It is chiefly through the symposia volumes that the Ciba Foundation promotes its name and activities. The total number of books published now exceeds 270, and these have been distributed and sold in almost every country in the world.

Titles for the symposia are derived from proposals submitted to the Ciba Foundation. The staff welcomes such proposals at all times, and every proposal is reviewed by the staff with the help of independent expert referees. Proposals for symposia topics should provide the following information:

1. Proposed title
2. Objectives
3. Topics to be covered
4. Supporting information

a. Background information--no more than 500 words

b. References--a maximum of eight, with an emphasis on recent reviews and major original articles

5. List of potential participants (approximately 12 key names).

Upon receipt, proposals are sent to two or three referees, who are asked to comment on the suitability of the topic for a Ciba Foundation symposium. Referees are reminded that the usual guidelines are:

1. There should be active research in the field.

2. The topic should bring together participants from a number of disciplines.

3. The topic should not be one which a specialist scientific society normally would deal with.

The staff also takes into account two other factors: whether similar or overlapping meetings are being organized by other groups, and the suitability of the topic for publication

Referees are also asked to suggest modifications to the proposal if they think the ideas are basically sound but capable of improvement.

The foundation makes its decisions on all proposals at periodic scientific-program planning meetings. All scientific staff participate in this meeting and, on one occasion each year, they are joined by the scientifically qualified trustees and members of the Executive Council.

Study Groups. These are groups organized on an occasional basis by the foundation. The objective of the study groups is to examine scientific matters of public concern and to help improve communication between scientists and the community. The groups meet for 1 day at a time extended over as many as 12 months. They explore problems and issues, collect information if necessary, and prepare a report or a series of recommendations. One such study group, dealing with child sexual abuse in the family, met nine times during 1983; it was organized by Porter.

Other Foundation Meetings. Discussion meetings are held for 2 to 3 hours and feature prominent scientists who happen to be in London for other business or who may, on occasion, be brought in especially for the meeting. The discussion meetings usually have a chairperson from one of the nearby universities. It is possible to have more than one speaker for such meetings. There is always plenty of time allotted for discussion. Thus far, over 300 discussion meetings have been held, more than 50 dinner meetings, five medical-student meetings, and over 200 other scientific meetings covering a variety of subjects. In addition, the Ciba Foundation organizes an annual lecture that has been given each year since the organization's founding.

Guest Meetings. The foundation lends its facilities free of charge to other scientific and medical organizations for the purpose of holding meetings, seminars, workshops and the like. More than 1300 guest meetings have been held at the Ciba Foundation headquarters, arranged by a wide variety of

national and international organizations.

Library and Information Services

The foundation maintains a small but well-equipped library that carries a wide range of scientific and medical books and currently subscribes to 180 journals. The library is used for reference by the scientific and editorial staff and by scientists attending meetings. It is also available to any postgraduate working or staying in London as well as to any scientist who may be in town for scientific meetings.

The Ciba Foundation publishes a quarterly bulletin that describes the foundation's activities and provides details of the information service. Langley, the information officer and librarian, provides information on overseas visitors and forthcoming British and international scientific meetings.

The staff of the Ciba Foundation also receives and responds to many requests for scientific information on a great variety of educational research, administrative, and international matters.

Accommodation

An interesting feature of the Ciba Foundation is the provision of sleeping and breakfast accommodations for scientists attending its meetings and also for scientists from all over the world who are making professional visits to London. Approximately 30,000 guests from 96 countries have stayed at the foundation. Visitors may apply to stay for periods up to 14 days (bed and breakfast only). Spouses of overseas visitors (but no children) may also be accommodated. Until very recently, this service was free, but operating costs have forced the Trustees to institute a charge of £15 (about $21) per night. Of course, the number of spaces is limited, and extra places are usually only available if there is not a Ciba Foundation symposium in progress.

Awards and Bursaries

Each year the Ciba Foundation makes a number of awards of several types.

Ciba Foundation Symposium Bursaries. This is a recently enacted scheme that is designed to enable young scientists between the ages of 25 and 35 to attend Ciba Foundation symposia as observers and subsequently spend 4 weeks in a senior participant's laboratory. All candidates must be active in research in the field in question and should be working in a laboratory or institute which is not represented at the symposium.

The bursary covers all travel expenses, using the least-expensive, practicable, direct means of travel (i.e., economy-class air fares using APEX wherever possible); accommodation at the Ciba Foundation during the symposium, with an additional amount for meals; and board and lodging during the candidate's visit to the host laboratory. It is anticipated that the recipient will stay in a university dormitory for the duration of this visit, or if a dormitory is not available, in a modestly priced hotel, guest house, or pension. The board and lodgings allowances are fixed using published international price guides.

Information concerning the bursaries and their availability is advertised by circular to members of the foundation's Scientific Advisory Panel and invited symposium participants, and by an advertisement in *Nature* or other journals. The bursaries are usually announced every 3 to 6 months and at least 6 months before the date of the relevant meetings.

Ciba Foundation/IUPAC Bursaries. The foundation, in collaboration with the International Union of Pure and Applied Chemistry (IUPAC), sponsors a small number of bursaries for young chemists from outside the UK to attend IUPAC Commissions each year. The purpose of these bursaries is to enable some of the younger, but established, chemists from university departments, scientific institutes, and the chemical industry to participate in IUPAC Commissions. The grants provide travel and living expenses during the commission of the candidate's choice.

Selection of candidates is based on: (1) their ability to contribute to the commissions, as well as to learn from them; (2) the possibilities of their making use of what they have learned when they return home; and (3) their future involvement in IUPAC activities. Applications are available from the foundation in January of each year.

In the past, the Ciba Foundation has also funded:

1. Anglo-French Exchange Bursaries
2. Royal Society of Medicine Associateships for Overseas Graduates
3. Awards to Technicians
4. Awards for Research into Aging.

In summary, the Ciba Foundation offers many services and makes a substantial contribution to communication in the biological and medical sciences. Its activities span the globe and touch a broad spectrum of research as it seeks to provide a stimulating setting for

free and informal contact between scientists.

For further information about the Ciba Foundation's activities, write to:

The Ciba Foundation
41 Portland Place
London W1N 4BN, UK
Telephone: (01) 636-9456
Telex: 27950/Ref. 514

The following list of recently published titles and forthcoming symposia helps illustrate the types of subjects covered by Ciba Foundation symposia.

Published Symposia

1. Cytopathology of Parasitic Disease, Ciba Foundation Symposium 99, 1983, 282pp, ISBN 0 272 79731 6, £25.00.
2. Development of the Vascular System, Ciba Foundation Symposium 100, 1983, 264pp, ISBN 0 272 79732 4, £25.00.
3. Better Crops for Food, Ciba Foundation Symposium 97, 1983, 256pp, ISBN 0 272 79729 4, £25.00.
4. Molecular Biology of Egg Maturation, Ciba Foundation Symposium 98, 1983, 318pp, ISBN 0 272 79730 8, £25.00.
5. Mobility and Function in Proteins and Nucleic Acids, Ciba Foundation Symposium 93, 1983, 367pp, ISBN 0 272 79657 3, £25.00.
6. Malaria and the Red Cell, Ciba Foundation Symposium 94, 1983, 268pp, ISBN 0 272 79658 1, £25.00.
7. Brush Border Membranes, Ciba Foundation Symposium 95, 1983, 350pp, ISBN 0 272 79659 X, £25.00.
8. Fetal Antigens and Cancer, Ciba Foundation Symposium 96, 1983, 272pp, ISBN 0 272 79660 3, £25.00.
9. Biology of Vitamin E, Ciba Foundation Symposium 101, 1983, 270pp, ISBN 0 272 79748 0, £25.00.
10. Cell Fusion, Ciba Foundation Symposium 103, 1984, 300pp, ISBN 0 272 79750 2, £25.00.
11. Mechanisms of Alcohol Damage In Utero, Ciba Foundation Symposium 105, 308pp, ISBN 0 272 79774 X, £25.00.
12. Functions of the Basal Ganglia, Ciba Foundation Symposium 107, 300pp approx., ISBN 0 272 79777 4, £26.50.
13. Basement Membranes and Cell Movement, Ciba Foundation 108, 320pp approx., 0 272 79778 2, £26.50.

Forthcoming Symposia, 1984

1. 23-25 October, Symposium No. 114; Fibrosis; organizer, Dr. David Evered.
2. 27-29 November, Symposium No. 115; Abortion: Medical Progress and Social Implications; organizer, Dr. Ruth Porter.

Forthcoming Symposia, 1985

1. 22-24 January, Symposium No. 116; Growth Factors in Biology and Medicine; organizer, Dr. Jonathan Nugent.
2. 5-7 March, Symposium No. 117; Melatonin and the Pineal; organizer, Dr. David Evered.
3. 16-18 April, Symposium No. 118; Molecular Biology of Macrophage Differentiation; organizer, Dr. Jonathan Nugent.
4. 21-23 May, Symposium No. 119; Immunogenicity of Peptides; organizer, Dr. Ruth Porter.

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COMPUTER SCIENCES

COMPUTER SCIENCE AT THE POLYTECHNICAL UNIVERSITY OF BARCELONA

by J.F. Blackburn. Dr. Blackburn is the Liaison Scientist for Computer Science in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until October 1984 from the National Academy of Sciences, where he is Executive Director, Computer Science Board.

The three main research activities in computer science at the Polytechnical University of Barcelona are computer networks, robotics, and programming.

Computer-Network Architecture

Several completed studies concern multibus multiple-processor systems. The multibus interconnection network is an attractive solution for connecting processors and memory modules in a multiprocessor system with shared memory. It provides a throughput which is intermediate between those of the single bus and the crossbar, with corresponding intermediate cost. The standard connection scheme for the multibus connects all processors and all memory modules to all buses. One study at Barcelona has shown that this standard connection scheme is redundant and expensive for a relatively large number of buses.

Reduced connection schemes were shown to produce the same throughput as the standard connection. The schemes are optimal with respect to the number of connections and are easy to arbitrate, reliable when a bus fails, and

expandable. The reduction is especially significant when the number of buses is relatively large, being 25 percent when the number of buses is half the number of memory mod s (Lang et al., 1983).

In anoth study a comparison was made of the e. ective bandwidth in a multiprocessor system with shared memory using the crossbar as interconnect versus using the multiple bus. A system of N processors and N memory modules was considered in which the processor requests to the memory modules were independent and were uniformly distributed random variables. Two cases were studied: in the first, a processor made another request immediately after a memory service, and in the second, there was some internal processing time between requests.

Simulation results showed that the multiple-bus interconnection network with the numbers of buses slightly higher than N/2 gave a very small degradation as compared with the crossbar. An organization with partial buses was proposed which was said to be more economical than the multiple bus for the same effective bandwidth (Lang and Valero, 1982).

A third study derived several designs for an m-user, b-server arbiter for use in interconnecting processors to memory modules in a multiprocessor system. A round-robin policy was applied in the designs of the arbiter. The iterative design is simple but relatively slow and does not use all the possibilities of integration. A network with one level of look-ahead is faster and more integrated. To increase even more the speed of arbitration, a design of two levels of look-ahead has been proposed. This network can be used effectively for up to 16 processors, memory modules, and buses (Lang and Valero, 1982)

Multistage shuffle-exchange networks have been used in single-instruction, multiple-data architectures for data alignment. Some of these multistage networks have been proposed as interconnection networks in multiprocessor systems. These proposals assume a random arbitration at every switch in the case of conflict.

A study at Barcelona has derived several methods to improve the bandwidth achievable with this type of network. These proposals are mainly based on introducing a preprocessing of demands before traversing the network; one or both of the following techniques are applied: (1) blocking some processors before entering the network to reduce the probability of blocking for the given distribution of demands, and (2) adding some extra information to the demands, to use it for a more intelligent arbitration at every switch. Simulation results show an improvement of 10 percent over previous proposals for random arbitration at a low cost in time and arbitration hardware (Labarta et al., 1983).

Finally, a mathematical model to compute the bandwidth of a multiple-bus interconnection network has been derived. Due to the computational complexity associated with the exact solution, the processors were removed from the queues at the end of each memory cycle to facilitate the analysis. This led to approximate solutions which are very accurate and easy to obtain (Valero et al., 1983).

Robotics

A microcomputer vision system for robot applications has been developed at Barcelona. The purpose is to recognize objects on a plane through contour information. The description of the object consists of a sequence of curvatures obtained by contour tracking. Recognition is based on similarities between the object being observed and models stored in memory based on a previous training phase.

The system consists of a specialized circuit for obtaining object contours using a gradient operator, and a low-cost microcomputer for recognizing the object and calculating its orientation.

Information supplied by a TV camera is handled by a specialized preprocessor which extracts the contour. The contour information is then processed by a microcomputer to get the sequence of curvatures describing the object. A 3×3 gradient operator is used to filter out information that is not useful and to correct for discontinuities.

The contour is tracked to get a sequence of point-to-point increments. Each element of the sequence of curvatures is obtained from a segment defined by k of these increments. Obtaining the object contour in this way leads to different sequences, depending on the object's orientation. This sequence is not invariant under rotation because of the different lengths of the increments. This length is 1 for horizontal and vertical directions and $\sqrt{2}$ for diagonal directions. The number of the increments that compose digitized straight lines of the same real length varies in a 1 to $\sqrt{2}$ ratio depending on the lines' orientation. The number of elements in the sequence of curvatures varies also in the same ratio. When a curved sector is analyzed, this ratio is not valid

because the increment lengths change according to their directions, and these variations tend to compensate.

A compensation is necessary to make the number of sequence elements describing the object contour independent from its orientation. This compensation has been applied to the straight lines by adding a number Na of null curvature elements, where:

$$Na = \frac{Np}{Cos\ \alpha} - Np,$$

with α in the interval 0 to 45 degrees, and Np is the number of elements and α the orientation of each sector.

Although the normalization--considering the whole object--is not exact, a random set of contours of different orientations was analyzed with a resulting dispersion in the normalized sequence length less than 10 percent.

The trajectory is determined by tabulating the 2^{11} possibilities that correspond to the value 1 or 0 of the eight surrounding neighbors of each point considered, and to 3 bits corresponding to the direction defined by the previous increments.

Each element Ci of the sequence of curvatures describing the object is computed as an average value of k-1 curvatures defined by the inverse of the radius of the circumference which passes through three consecutive contour points. The value Ck is obtained by tabulating the 2^{3k} combinations determined by k consecutive contour increments. The chosen value of k is determined as a compromise between cost and performance. When k = 4 there is good vertex enhancement (in this context vertex means the contour sector with highest curvature value), and 4K bytes of memory are enough to tabulate all the possible curvatures defined by the increments. The mean value of the three computed values gives the elements Ci of a new filtered sequence.

The recognition is done in two stages. The first one selects from among the models those which have the same perimeter as that of the object being identified. This perimeter corresponds to the number of elements of the curvature sequence already normalized. The comparison of the sequence obtained from the contour object with the models already selected is made through maximization of a similarity function.

The orientation of the visualized object is measured by the angle formed by one reference axis in the model and the homologue axis in the object (Casals and Amat, 1984).

Programming Research

The programming research at Barcelona ranges over a fairly wide spectrum, including programming with abstract data types and program schemes and parallel programming.

Abstract data types and program schemes are used in several methods of program construction. One study at Barcelona shows how to synthesize these two approaches, interpreting a program scheme as a generic program written using abstract operations of some well-specified data types.

In recent years data abstraction has been recognized as a useful programming tool. The methodological aspect of the use of data abstractions in program construction was the main consideration in this study. The most intuitive approach is using them as a tool to build user-defined data types and employing the operations provided to write programs. This approach is useful for adding data structures like stacks, queues, and trees.

A second approach is to design the entire program as a hierarchy of abstract data types. At Barcelona the interest has been in methods that deal with the updating of the stepwise refinement method for use with imperative languages supporting encapsulation mechanisms. The researchers have developed an imperative language, called Merlin, for tracking programming with abstract data types. Merlin is bilingual in Catalan and Spanish (Botella, 1983).

Another study provided program schemes for the design of parallel algorithms for a wide variety of cases. Until recently research on parallel programming has been centered on the development of models for which relatively simple semantics could be developed. Meanwhile, little attention was paid to the construction of algorithms. Researchers have developed two program schemes which are characterized by the notions of cooperation and concurrence. A notation was developed which preserves the characteristic simplicity of algorithms oriented to indefinite execution in a context where termination of the process is expected (Llamosi, 1984).

A third study was concerned with computability on abstract data types. Computability issues may be studied in two ways. One method is translating the abstract data types, through some kind of coding, to the natural numbers and then using classical computability theory. A second, more abstract notion of computability may be needed, independent of any data type. This latter notion is called implementability. At Barcelona

two aspects of implementability have been studied: the relation between implementability and the information provided by a data type, and the characterization of when implementability does coincide with computability and finite specificability (Orejas, 1983).

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6/12/84

MICROPROGRAMMING RESEARCH AT THE AUTONOMOUS UNIVERSITY OF BARCELONA

by J.F. Blackburn.

Microprogram control for general-purpose computers came into widespread use with the IBM System/360 compatible line of computers introduced in 1964. The principal value at that time was the ability to easily emulate the operations of earlier noncompatible computers through microprogramming. Many other uses of microprogramming have since evolved. The Autonomous University of Barcelona, Spain, for example, is using microprogramming for tuning user-program architecture, handling register allocation, and doing vertical migration.

Tuning Architecture

The aim of one project was to automatically tune the architecture of a microprogrammable computer to a given program. It has been determined that less than 4 percent of a program generally accounts for more than half of its running time. This justifies the search for the loops in a program which take the most time in execution.

The method at Barcelona begins with an analysis of the user's program to identify all the instruction sequences which can be microprogrammed to produce new instructions. To select the sequences which yield the greatest time saving in program execution, a set of parameters is associated with every sequence.

Segments and loops can be microprogrammed. A segment is the largest set of instructions that has only one entry point and one exit point and that is always executed sequentially from first to last. A set S of segments constitutes a loop if there is a path from each node of set S to each other node of S.

A loop is microprogrammable if all its exterior entries occur in the same segment. Two segments are said to be similar or functionally equivalent if they are made up of the same instruction sequence (in general with different parameters).

A class of equivalence r_i is made up of two or more similar segments. The representative for a class of equivalence r_i is e_i. All the elements of one class of equivalence, to define the same new instruction, are interpreted by the same microprogram; therefore, less control memory will be used if such instruction is included in the program.

Starting with the segments and loops of a program which can be microprogrammed, researchers at Barcelona have developed a method for selecting loops and segments which, when converted to a microprogram, minimize the execution time for a given size of the control memory. In the process of selection, the constraints which can exist between elements of a set have been taken into account, with emphasis on the procedure when encountering elements which intersect (Luque and Ripoll, 1980).

Register Allocation

Another project developed a dynamic procedure for allocating internal registers of a microprogrammable system. The procedure yields an optimal allocation that minimizes the execution time of the microprogram generated. The method assumes that the control flow of the program to be microcoded is represented by a directed graph. Allocation and deallocation of the variables to the registers are carried out in each edge of the graph. Integer linear programming is used for the selection of the variables to be assigned to the registers in each node.

The principal aim of the project was to develop a procedure for global internal-register allocation which minimizes the execution time of the program to be microcoded. The number of registers is assumed to be smaller than the number of variables defined in the program. The allocation procedure considers the behavior of the variables in each basic block of the program and the control flow from one block to another.

The program to be microcoded is represented by a control flow chart in which the set of nodes $N=[A_0,\ldots, An]$ represents the basic blocks (straight-line codes) and the set of edges the transitions between them.

The problem of finding which variables should be assigned to each register for each node, so that the time saving in the execution of the microprogram is maximized, has been stated formally in terms of a formula to maximize the time saving. The formula includes a term representing the time saved by loading the variable into an internal register, another term giving the time included in loading a variable into a register if in the immediately preceding nodes the variable was not loaded, and a term representing the time spent in deallocating a register if in the immediately succeeding nodes the variable does not remain assigned to a register (Luque and Ripoll, 1984).

Vertical Migration

As far back as 1951, M.V. Wilkes discussed the potential of microprogramming as a means for altering the architecture of a given computer system: "The matrices (read-only memories storing micro-operations) may be regarded as very high-speed stores holding fixed information. If they could be replaced by an erasable store to which information could be transferred from the main store of the machine when required, we should have a machine with no fixed order code; the programmer would, in fact, be able to choose his order code to suit his own requirements and to change it during the course of the programme if he considered it desirable. Such a machine would have a number of fascinating possibilities but I doubt whether, in view of the amount of equipment it would doubtless involve, its construction could be justified" (Wilkes, 1951).

E. Luque and A. Ripoll have developed a system called "Vertical Migration" to use microprogramming to make the architecture of the computer more fully support the primitives of programs that solve a given problem. The term "vertical migration" refers to a performance-improvement technique in which the selected functions or program primitives are moved to an optimal lower level within the multiple levels (layers) of a software/ firmware hierarchy on a single processor. General-purpose, dynamically microprogrammable computers offer the possibility of adapting (tuning) their architecture by vertical migration of primitives from software to firmware. Two types of architecture synthesis using microprogramming can be identified:

1. Functional architecture synthesis. In this type the programmer microcodes software functions that previously have been heavily used in areas of applications.
2. Problem-oriented architecture synthesis. This type refers to the automatic replacement of code by functionally equivalent microcode in specific programs analyzed individually.

The first type defines, totally or partially, the virtual machine for the application area, whereas the second defines a virtual machine which is only valid for its program.

The functional architecture synthesis has been applied successfully to operating systems and to processors defined by high-level languages.

For the problem-oriented architecture synthesis the approach may be heuristic or analytical. A heuristic process may include environment partitioning or classifying problems according to function, tracking program execution with minimal overload, synthesizing the architecture, verifying synthesized microcode, and passing architecture changes to system translators.

In architecture synthesis the specialized architecture is synthesized iteratively, one instruction at a time, until an instruction set is formed with a minimal expected execution time.

The analytical approach assumes the problem is stated in a high-level language which is translated by the

compiler into an intermediate language representative. Instead of the normal code generation of the compiler, the following operations take place:

1. Generation of microprograms that define a new architecture that efficiently supports the higher-level-language program being compiled.
2. Generation of the machine language program that uses the new architecture (Luque and Ripoll, 1981).

The analysis and experimentation with microprogramming at the Autonomous University of Barcelona is at a high technical level and covers a rather important aspect of research in computer science.

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6/21/84

SPANISH DEVELOP INTERCONNECTION STRATEGY FOR MICROPROCESSORS

by J.F. Blackburn.

Many universities are implementing large multiple-processor systems built around an array of commercial microprocessors. (See, for example, *ESN* 36-12: 323-325 [1982] and *ESN* 37-10/11:400-403 [1983]). Systems with as many as 10^4 processing units are being planned to speed up the maximum throughput rate for future super systems. However, the interconnection network linking together array elements is a serious bottleneck for the practical realization of such systems. As the size of the network increases, so does its complexity--which makes many design approaches impractical because of the hardware cost for the interconnecting circuitry. The various schemes that have been proposed for the interconnection network are all dependent on the number of processing elements to be included. When the processing elements are microprocessors, as they usually are, the problem becomes more acute since the cost of the interconnection network becomes the dominant cost of the system.

At the University of Seville, Spain, this problem has been studied extensively, and two situations have been distinguished. There are systems using conventional interconnection networks that have prohibitively expensive hardware and link 64 or more processors; and there are systems that take advantage of specific microprocessor characteristics but are limited to the interconnecting of eight or fewer processors.

Professor J.L. Huertas and his colleagues have developed a new interconnection strategy which leads to a network complexity proportional to N/k (where N is the number of processing elements and k is a positive integer whose value depends on the minimum clock period of the microprocessor used, the memory access time, and the time delay associated with the network connection). In the conventional strategy the network complexity is proportional to N. The approach is based on a time-sharing use of standard microprocessor buses and may be applied to commercial microprocessors.

In the Seville strategy the interconnection of N processors with N memory blocks is accomplished as follows. The set of processors is partitioned into k identical clusters. The processors are denoted by

$$p_i^j \quad (i = 1, 2, \ldots N/k;\ j = 1, 2, \ldots k).$$

Memory blocks are grouped forming k identical maps, every map having m blocks (m=N/k). Blocks are identified by

$$M_r^q \quad (r = 1,2,\ldots,k;\ q=1,2,\ldots,m).$$

Figure 1 gives an example of the case where N = 12.

The system is restricted as follows:

1. Any processor is able to address any memory block during a read operation.
2. During a write operation, a given processor p_i^j is only able to address memory blocks, M_r^q, with j=r.

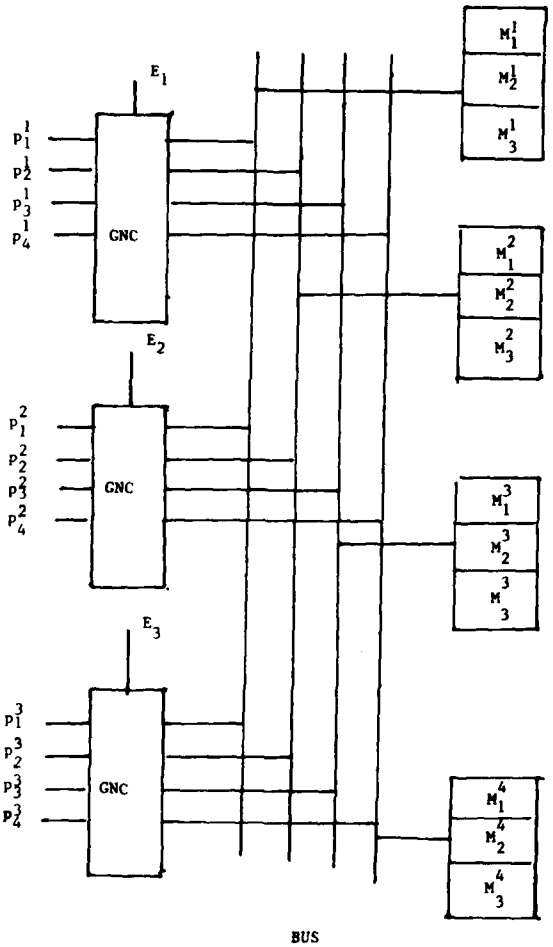

Figure 1. Twelve processors with 12 memory blocks.

3. All the processors of the jth cluster receive the same clock signal.

4. Clock signals for every cluster have the same period T but are shifted by T/m, as is shown in Figure 2.

5. Auxiliary enable signals are derived from clock signals following the diagram of Figure 2.

6. Every block named GNC[j] (Generalized Network Connection) can realize any one of the m^m different interconnection patterns linking the m processors from a cluster j with the m memory maps during a suitably chosen unit time interval.

The kth interconnection cycle is defined as the time interval between the rising slope of E^1 in Figure 2 and the falling slope of E^k. We need to evaluate the number of different interconnection patterns which may arise during an interconnection cycle. Let I_T equal the total number of patterns, and let I_j equal the number of patterns which may arise during the jth interconnection cycle. The value of I_j can be computed

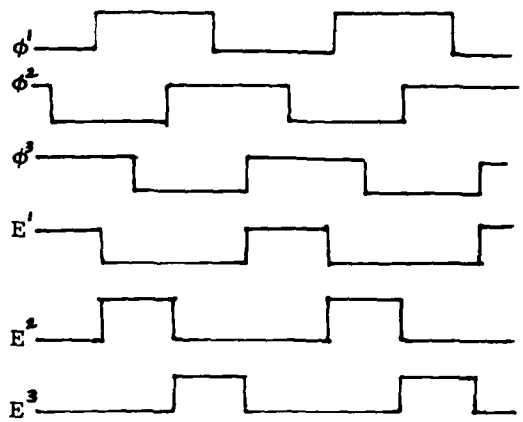

Figure 2. Cycle shifting.

by considering that within the jth interconnection cycle we can connect m processors with N memory blocks.

We may write

$$I_j = m^m \cdot k^m = N^m, \text{ since } m \cdot k = N \text{ and}$$

$$I_T = \prod_{j=1}^{k} I_j = N^N.$$

The same number of interconnection patterns may be obtained from the described architecture as that obtained from one GNC with N inputs. However, since k GNCs with m inputs were used, the complexity is reduced. For example, if crossbar switches are employed, the complexity of the interconnection network is dependent on m·N as compared to N^2 using N inputs to each GNC.

In practice the system is constrained by the typical access time of commercially available memories. An empirical "optimum" may be considered for k = m = 8, allowing an inexpensive interconnection for 64 processors with 64 memory blocks.

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6/14/84

ELECTRONICS

NETWORK RESEARCH AT THE UNIVERSITY OF SEVILLE

by J.F. Blackburn. Dr. Blackburn is the Liaison Scientist for Computer Science

in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until October 1984 from the National Academy of Sciences, where he is Executive Director, Computer Science Board.

The University of Seville, Spain, has a very active research group in the Department of Electromagnetism and Electronics. The department's 20 professors and associates have published more than 100 significant papers since 1976. The work in electromagnetism is mainly in microwaves and electrohydrodynamics. The electronics research covers a very broad spectrum, including logic design, analysis and synthesis of networks, digital oscillators and filters, architecture of multiprocessor systems, computer-aided design and simulation, digital signal processing, the design of integrated circuits, and certain applications--e.g., scientific instrumentation.

This article reviews some of the work in the analysis and synthesis of networks.

SPL N-Port

One project deals with the synthesis of resistive n-port section-wise piecewise-linear networks. This effort has shown that every n-port resister not necessarily reciprocal represented by a section-wise, continuous, piecewise-linear (SPL) multidimensional function can be realized by a circuit containing only two-terminal, continuous, piecewise-linear resistors and a nonlinear converter called a transformer-like converter. This means that an n-port can be exactly realized by the technique developed at Seville. And since a practical method for building an n-port is to approximate its functional description by an SPL function, the approach is of interest beyond the synthesis of SPL multiports.

The procedure can be considered as a general method for synthesizing an n-port given by the value of its coordinates at a set of data points. Finite-jump discontinuous functions may also be synthesized in a direct extension of the procedure used for the SPL function.

The decomposition scheme for the SPL n-port was developed in connection with the mathematical structure of the function to be realized. The linear and nonlinear subnetworks have a well-determined configuration and can be directly synthesized.

From the point of view of practical synthesis, all of the linear and nonlinear subnetworks involved in both the direct synthesis and the decomposition introduced can be implemented by a unified technique (Huertas and Rueda, 1982b).

Modeling Nonlinear N-Port Networks

Another study resulted in a new procedure for representing multidimensional characteristics associated with a resistive n-port network. The new functions are an extension of SPL functions and can be useful for approximating and synthesizing nonlinear networks. Two subclasses (polynomic and spline-wise-multidimensional functions) were considered in detail to obtain their associated canonic global representations.

The main advantage of the section-wise uniform representations developed is that the approximation is not restricted to piecewise-linear functions, and it leads to more powerful approximating tools. The required accuracy and the degree of smoothness are the only criteria for selecting the approximating functions. This is important when section-wise piecewise uniform (SPU) functions are used for modeling nonlinear devices or circuits.

SPU functions admit a closed-form canonical representation. The coefficients associated with these functions can be computed and stored at a reasonable cost, and the same computing procedure can be used as for the SPL characterizations. Furthermore, the canonical representation is formally identical to that corresponding to the SPL ones. This means that the synthesis method for the latter can be used for the former (Huertas and Rueda, 1982a)

Multiport Networks

Section-wise models for linear and nonlinear multiport networks were the subject of another project. In this research effort global piecewise representations for multiport resisters were designed by using operational amplifiers. The inadequacy of general SPL functions for describing such networks was shown. Explicit global descriptions which are piecewise linear (at least inside a bounded region) were found to be more efficient representations.

Resistive multiports realized by using active circuit elements admit a global description representing the network both inside and outside the dynamic range of the components. That characterization does not depend on the particular n-port but on the circuit structure (Huertas and Rueda, 1983)

Nonlinear Switched-Capacitor Networks

Another project shows that switched capacitors can be efficiently used for designing nonlinear networks. The proposed design methods are fully compatible with general synthesis methods for nonlinear n-ports. Several circuit alternatives have been evaluated.

The basic component, the switched-capacitors (sc) resistor, is an extension of the switched capacitor used now in linear filters. The sc resistors allow for the design of ultra-descrete-time or continuous-time resistive networks. Components other than resistors may also be synthesized with only small changes in the mutator (Chua, 1969). The techniques can be extended to networks containing nonlinear capacitors, inductors, and higher-order elements (Huertas et al., 1984).

The quality of research in electronics at Seville University is high, as evidenced by the researchers' strong publication record since 1976. Their papers have been accepted by major publications, such as the proceedings of the Institute of Electrical and Electronics Engineers (IEEE), Proceedings of the International Symposia on Multiple-Valued Logic, and IEEE Transactions on Computers. The work on realizing a resistive nonlinear multiport is in the forefront of research in nonlinear network synthesis. Prof. Huertas is a recognized authority in this field.

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6/15/84

GENERAL

RESEARCH AT THE EC'S ISPRA CENTER

by James W. Daniel, Scientific Director for Europe and the Middle East for the Office of Naval Research's London Branch Office. Dr. Daniel is on leave until August 1985 from The University of Texas at Austin, where he is Professor of Mathematics, of Computer Sciences, and of Education.

Although established and continuing primarily as an energy-research center, the European Communities' Joint Research Center at Ispra, Italy (JRCI), has developed strong supporting programs in a number of areas of interest to the US Navy R&D community. On a recent visit I learned about their work in materials science (especially nondestructive testing), remote sensing and environmental science, computational and experimental mechanics, and seabed studies related to radioactive waste disposal.

The Center

The 1957 Treaty of Rome required the establishment of research centers to support European development of atomic energy. Four Joint Research Centers were created: in Geel, Belgium, with linear accelerators and a nuclear metrology bureau; in Karlsruhe, Federal Republic of Germany, with a plutonium-fuels laboratory and The Transuranium Institute; in Petten, The Netherlands, with a high flux fission reactor and a laboratory on high temperature materials; and in Ispra, with a broad program of research now including fission-reactor safety and waste management, environmental protection, fusion technology and safety, and non-nuclear sources of energy.

The combined 1984-87 budget for the four centers is about $560 million; JRCI's is by far the largest at about $375 million. Most of the JRCI budget goes to the four programs just mentioned; reactor safety and waste management takes about 58 percent, environmental protection about 21 percent, fusion about 9 percent, and other energy sources about 8 percent. Analyzed from a resource viewpoint, the JRCI budget devotes 35 percent to its 800-strong permanent research staff, 28 percent to support staff, 17 percent to nonpersonnel research costs, and 20 percent to nonpersonnel support costs.

JRCI has a matrix organization. It is divided into columns along disciplinary lines by three departments: Informatics, Mathematics, and Systems Analysis is headed by P. Bonnaure; Applied Sciences and Technology by H. Holtbecker; and Natural Sciences and Physics by the JRCI Director, G.R. Bishop. The row divisions represent formal projects, coordinated by the Projects Director R. Klersy; representative projects are

those on remote sensing applications, on environmental protection, and on fusion technology.

Besides its research activities, JRCI engages in an extensive educational program of research seminars and of both basic and advanced courses in specialized disciplines. Lecturers come from the Ispra Center and from universities, research centers, and industries throughout the world. Most of the educational programs concern aspects of nuclear energy--quality assurance in plants, energy planning, risk assessment, and the like. Some, however, are of more immediate relevance to the US Navy R&D community; such 1984 programs include the Advanced Seminar on Structural Reliability (June), Reliability and Data (October), Computer Simulation in Physical Metallurgy (May), Introduction to Image Processing for Remote Sensing (August), and Synthetic Aperture Radar Principles and Applications to Earth Resources Evaluation (October). Information on Ispra courses is available from the Ispra Courses Secretariat, Centro Comune di Ricerca, I-21020 Ispra (Varese), Italy; phone (010-39-332) 789819.

Materials Sciences

JRCI researchers are interested in materials primarily as they affect reactor safety. One such project is headed by S. Crutzen; on behalf of the center he oversees the Program for Inspection of Steel Components (PISC), an international project of the Committee on Safety of Nuclear Installations (appointed by the Organization for Economic Cooperation and Development). PISC-I started in 1973, followed by PISC-II in 1982. This present project involves round-robin testing--by some 50 laboratories in 15 countries--of four reactor pressure-vessel plates containing artificial defects; various nondestructive test procedures are used by the different laboratories, most based on ultrasound techniques. The test plates are now arriving back at JRCI, where they will be cut up to reveal the true defects, and where analyses will be performed to assess the performance of various test procedures. PISC-III will later validate the best procedures on real defects, on other components of reactors, on artificial defects in samples with more realistic geometries, and so on.

Another materials project is headed by P. Rocco. His group is studying the effect of the fusion process on the fatigue, crack-growth, and torsional creep properties of materials used in containment vessels for plasmas in fusion reactors. Their work has concentrated on low-nickel-alloy steels, simulating the impact of fusion either with the high flux fission reactor in Petten or with Ispra's cyclotron. They have also developed and tested various coatings and armors for the steel.

Remote Sensing and Environmental Science

G. Fraysse heads a group working in this area; their primary goal is to assess the feasibility of establishing in the 1990s worldwide information systems to assist in the efficient use of land for agriculture and in the monitoring of coastal marine pollution, especially for the Mediterranean Sea; in general the group does not develop sensors or other technology, but instead attacks the systems problems of effectively using existing technology. They have developed a spectral/time-domain method for processing remote sensing data; this allows them not only to detect marine oil spills but also to characterize the hydrocarbons involved. Another project developed signal-processing algorithms that correct for the atmospheric interference in satellite-gathered oceanographic data. They have also conducted a careful study of the applicability of synthetic aperture radar data for providing information on proper land use for agriculture. A related project models the Adriatic Sea, its inputs, and air-sea interactions in order to simulate the behavior of coastal pollutants.

Computational and Experimental Mechanics

A very strong group headed by J. Donea conducts basic research in computational and experimental mechanics. They developed finite-element algorithms and software to simulate the behavior of a structure submerged in a fluid when an explosive charge is detonated in the fluid; their application is to accidents in reactors. They then validated their code experimentally by carefully measuring the structural stresses in laboratory tests. The present code only handles two-dimensional problems, but a three-dimensional capability is under development. Similar codes have been developed for simulating the convection and diffusion phenomena in reactor meltdowns. In an unrelated effort, this group is also assessing the need for a large (area of at least 50 m^2 and capacity of at least 100 metric tons) vibration table to be built in Europe; the largest European table now is about 4 m×4 m and can handle about 50 metric tons.

Seabed Studies

One method being internationally studied for the disposal of radioactive

waste involves burial in the seabed. F. Girardi and N. Murray head a JRCI project studying this. The idea is to place containers of waste in torpedo-shaped vehicles which are dropped, perhaps with some boosting propulsion, to the seabed in ocean depths of, say, 5 km. The projectiles reach terminal velocities of about 200 km/h. and penetrate the seabed to depths of about 40 m. This approach is considered as an alternative to drilling depository holes because of the desire to use waste containers with diameters several times larger than that of the holes readily drillable with present technology. The JRCI group is studying methods to simulate the behavior of the projectile and the hole it creates, to measure properties of holes created by experimental projectiles, and to analyze the component materials of the seabed at these great pressures (hundreds of atmospheres).

Representative Publications

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5/25/84

MATERIAL SCIENCES

MATERIALS ISSUES IN GAS TURBINES

by Kenneth D. Challenger. Dr. Challenger is the Liaison Scientist for Materials Science in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until May 1986 from the Naval Postgraduate School, where he is Associate Professor of Materials Science.

The Gas Turbine Division of the American Society of Mechanical Engineers held its 29th Gas Turbine Conference and Exhibition in Amsterdam, The Netherlands, from 3 through 7 June 1984. It is significant that the meeting was held in The Netherlands because it emphasizes that country's efforts to attract industrial investments; gas-turbine design, manufacturing, and repair is one of the promising high-technology areas in which the Dutch hope to attract both national and foreign investment. This was made very clear by Mr. G.M.V. van Aerdenne, Minister of Economic Affairs, in his opening address to the conference; he emphasized that reindustrialization in selected areas is a key point in The Netherlands' economic recovery (see also *ESN* 38-8:442-443 [1984]).

The conference, covering all aspects of the gas-turbine industry, included over 88 technical sessions and a massive exhibition of gas-turbine-related hardware. The subject matter of the technical sessions was very diverse, ranging from fundamental studies of fluid flow, thermodynamics, and corrosion to operational experience with coal-fired systems. Several panel discussions were organized around the most current problem areas in gas-turbine improvement. Papers were presented by authors representing over 20 countries, and over 5000 participants attended.

This article highlights the material covered in five technical sessions on the metallurgy of gas-turbine components and two sessions on ceramic materials and components.

Corrosion problems and the development of seal materials were singled out as the main material issues. Considerable progress has been made in the development of new airfoil alloys and coatings for these alloys. (In some instances, coatings provide oxidation and corrosion protection and in other instances act as thermal barriers to reduce the metal operating temperature.) Mainly two problems have motivated the research in these areas: the cobalt crisis in 1979 (as a result, very few alloys now require cobalt) and hot corrosion by molten sulfate salts. Increased understanding of hot corrosion mechanisms has improved engine life so much that, in my opinion, another problem that can limit engine life is about to be revealed--bearing life. The use of gas turbines in marine vehicles has already resulted in some problems with the shaft bearings. The problem stems from the non-steady state operation, which causes changes in the axial load on the shaft bearings. Aircraft and

land-based gas turbines operate at essentially one speed once takeoff or start-up has occurred, whereas ships frequently require power changes from the turbine.

The coating of steel bearings for improved life is being considered but was not discussed at this conference. The development of ceramics for bearing applications was, however.

Ceramics in Heat Engines

Papers were presented on the development of Si-SiC bearings (A. Krauth and L. Berroth, Rosenthal Technik AG, West Germany [FRG]) and Si_3N_4 bearings (M. Torti, J. Hannoosh, S. Hanstine, and D. Arvidson, Norton Co., Worcester, MA). The Si-SiC bearings are made by dry-pressing SiC powder and siliconizing (impregnation by vapor and liquid Si), achieving a density of 3.07 gm/cm^3 and bending strength of 380 MPa. The Si_3N_4 bearings are made by hot-pressing very fine (20 μm maximum grain diameter) Si_3N_4+1% MgO powder. Careful preparation of the powders (by proprietary processes) was credited with the improved fracture toughness, 5.5 $MNm^{-3/2}$ and room-temperature bending strength of 800 MPa. The contact-fatigue life of Si_3N_4 bearings was shown to be an improvement over M-50 steel bearings at room temperature, but the main advantage of the Si_3N_4 bearings begins to be realized as temperature exceeds 250°C, when M-50 begins to lose strength; in contrast Si_3N_4 retains its strength to 1000°C. In addition to improved operating performance, the ceramic bearings are lighter than steel (3.2 gm/cc compared to 7.6 gm/cc), have twice the hardness, low friction coefficients (μ<.2 dry against steel or itself), and high gall resistance.

Adiabatic diesel-engine development was one of the main topics discussed that involved ceramic research. Cummins Engine Co. (US) and the US Army Tank-Automotive Research and Development Command have developed an engine in which the combustion chamber is insulated with ceramics, increased combustion chamber temperatures occur, and the thermal efficiency increases from 35.6 percent to 48 percent by recovery of the thermal energy from the exhaust gas. Y. Hamano and M. Yomamoto (Kyocera Corp., Japan) have constructed an uncooled, three-cylinder direct-injection diesel with ceramic material. Sintered Si_3N_4 was used throughout this initial engine, but research on SiC and PSZ (zirconia partially stabilized with Y_2O_3), continues in an attempt to increase durability. SiC could extend the operating temperatures as it retains its strength to 1400°C. However, Si_3N_4 has the best thermal shock resistance of these materials. The PSZ has the best adiabatic properties due to its very low thermal conductivity (3.8 W/m°K compared to 71 W/m°K for SiC), but loses strength rapidly above 200°C--so it is best suited for the low-temperature regions of the engine. The development completed by Kyocera and that under way will certainly make them a very competent and competitive supplier of ceramic engine components in the near future.

Fiber-Metal Abradable Seals

Pressure losses between the ends of the rotating turbine blades and the surrounding shroud are a large factor in engine performance, and ceramic seals might help reduce these losses. However, many difficulties remain, and at present the abradable metal-fiber seals seem the best solution.

The wear mechanism of the fiber-metal abradable seals is now understood. The superior performance--low wear energy (no damage to the blades) and very fine, nondamaging downstream wear particles--is due to the fracture mechanism of the fibers. R. Toloran and M. Beaton (Brunswick Corp., DeLand, FL) reported that the fibers break into very small pieces during wear by a low-ductility mechanism. Figure 1 illustrates the typical microstructure of these materials. They are, in general, only about 20-percent dense; each fiber is about 10 μm in diameter by 100 μm in length and consists of several grains. The high surface-free energy of the grain boundary and the resulting thermodynamic force to reduce the total grain-boundary surface area causes notches to form at each grain boundary along the length of each fiber. The high surface-free energy of the grain boundary also results in the nucleation of second-phase particles on the boundary (arrow in Figure 1). This second phase is mostly carbide in the alloys studied (Haynes 188, FeNiCrAlY, Hastelloy X). These carbides are strong but brittle. Thus, during rubbing the strain is concentrated by the notches, and the brittle microstructural constituents are induced to fracture in at least a semi-brittle manner.

These seals are available commercially under the trade name Brunslloy. Seals are available for use up to 900°C (25Ni-18.5Cr-9Al-.02Y) with various mechanical properties. Their mechanical properties are a function of the seal density (low permeability and high strength from high-density products), but the best abradable characteristics are obtained from materials with the

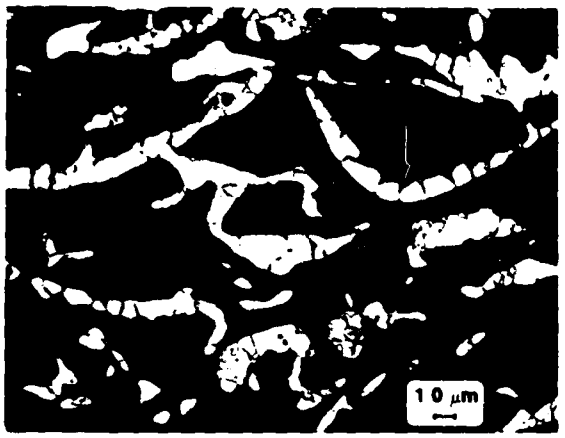

Figure 1. Cross section of Hastelloy X 10 μm fibers. Note the irregularity of fiber cross sections, the association of grain boundaries with narrow points in the fibers (notches), and the occurrence of second phase particles in these grain boundaries; an arrow (upper right) indicates one such area (Tolokan and Beaton, 1983).

lowest density. Thus, design trade-offs are required.

Coatings

By far most papers related to gas-turbine materials were concerned with protecting the high-temperature turbine components from oxidation and corrosion. Although the damage from hot corrosion and the repair of this damage are the most critical materials problems in gas turbines, there was not a single paper from a major engine supplier (General Electric, Pratt and Whitney Aircraft, and Rolls Royce) on this topic. Their problems in this area and solutions appear to be quite proprietary.

Several papers were presented on the topics of hot corrosion in the turbine and of electrochemical corrosion in the compressor. This is a subject on which The Netherlands (at Elbar BV, Lomm, and the National Aerospace Laboratory [NLR], Amsterdam) has focused its materials research. H. Kolkman and A. Mom (NLR) coauthored two excellent papers covering corrosion in both the compressor and turbine sections of a gas turbine. In the compressor the corrosion is electrochemical, the water coming from the hygroscopic nature of the deposits found in the compressor section; these deposits come from the intake air. Use of turbines on land only results in NH_4^+ and $SO_4^=$ as the dominate ions in the deposits; turbines used over the sea (aircraft and ships) contain predominately Na^+, $SO_4^=$, and Cl^-. Not only are the sulfate and chloride salts hygroscopic--which results in galvanic, pitting, intergranular, and stress corrosion in the compressor--but they spall off the compressor components and cause sulphidation corrosion downstream in the turbine section.

The solutions to this corrosion problem include washing the compressor frequently, filtering intake air, and coating the compressor components. The erosion characteristics of the heat-resistant organic paints normally used for this purpose were studied using a newly developed test rig. In this rig, the erosion rate can be measured as a function of attack angle and temperature. In general, the rate of erosion is greatest for very small angles of attack. Fortunately, the angle of attack is large for most sections of an airfoil, but the angle is very low near the leading edge. Even with these limitations, it was reported that the corrosion was less in compressors that had been coated.

Hot corrosion of the turbine airfoil materials and procedures to repair rather than replace the components attracted the greatest participation in the materials sessions. The trend of repairing instead of replacing turbine components is rapidly increasing. Already commercial aircraft engines fly with weld- and braze-repaired turbine blades; more badly damaged components will be repaired and reused in the near future.

This new material requirement (i.e., repairability) is leading to the development of more weldable and brazeable structural materials in the turbine. The Cabot Corp. (D. Klarstrom, H. Tawaney, D. Fluck, and M. Northman) reported the development of a non-cobalt-containing, nickel-based alloy that is solid-solution hardened for improved weldability. It is available in sheet product forms for combustors and other structural components in the hot sections of the engine. The development of this alloy used the concept of the electron vacancy number to balance the composition so as to avoid the formation of the intermetallic topologically close-packed phases. The formation of these intermetallic TCPs (laves, sigma, mu) during service leads to a dramatic reduction in ductility that makes weld repair of currently available alloys very difficult.

Hot corrosion occurs due to the presence of a molten sulfate salt. The salt can come from many different sources that are difficult to eliminate, thus it is a problem that must be solved by developing materials or coatings

resistant to attack by the molten salt. Mom and Kolkman (NLR) presented an excellent review of the mechanisms of hot-corrosion attack and the various mechanisms used to combat the attack. The molten sulfate salt attacks and penetrates the protective oxide scale of the alloy or coating. Once the coating has been breached, rapid or even catastrophic oxidation occurs. Hot corrosion is generally the life-limiting factor in industrial and marine gas turbines.

It has been shown that the replacement of IN738 with IN939 as the first-stage material for industrial gas-turbine blades will lead to a much better corrosion resistance due to the higher Cr content of IN939 (R. Schneider, R. Bauer, M. Stoubli, and A. Grunling; Brown, Boverie, and Cie AG; FRG) The NiCoCrAlY overlay coatings are most suitable for land-based aircraft, whereas the Pt-modified aluminides and the CoCrAl based overlay are most applicable when NaCl intake is likely.

In a fundamental study of the effect of low pressure, ∿0.1 atmosphere (76 Torr), on the heat transfer to a particle in a thermal plasma, it was found that the Knudsen effect dominates the heat-transfer mechanisms rather than the variations in thermo-physical properties with pressure (X. Chen and E. Pfender, University of Minnesota). This has important implications for the plasma spraying of coatings as the particle sizes that can be used for low-pressure spraying are limited due to the Knudsen effect. Low-pressure spraying is desirable when plasma spraying a protective metal coating because air entrapment when spraying at 1 atmosphere can result in the formation of defects in the coatings that lead to their early failure.

The representatives from The Netherlands and Brown, Boverie, and Cie were very open about their research on this topic, but as mentioned previously, the "big three" engine suppliers were quiet.

Thermal-fatigue failure of coatings is known to be a problem, but there were no discussions of, or presentations on, this subject.

In summary, materials problems continue to limit the operational life of gas turbines. Hot corrosion of the turbine airfoil materials is, at present, life-limiting, but improvements in substrate alloys and the protective coatings for the airfoil components will shortly extend engine life to the point where some other life-limiting factor is encountered. It appears that this will be bearing life and that the most likely solution to this problem will be a change from standard steel to ceramic bearings.

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6/22/84

MATERIALS RESEARCH AT IMSE AND HPRC, POLAND

by R.W. Armstrong. Dr. Armstrong, formerly Visiting Fellow of Clare Hall while on sabbatical leave at the University of Cambridge, Department of Metallurgy and Materials Science, is now at the University of Maryland, College Park, MD.

Warsaw Technical University's Institute of Materials Science and Engineering has a small but exceptionally active group of researchers investigating how the strength of polycrystal and amorphous metallic materials depends on microstructure. Professor M.W. Grabski is director and dean of the faculty at the institute, which has 250 students and 180 staff members, including 50 professional scientists and engineers.

Since 1970, Grabski has concentrated on the influence of the specific structure of grain boundaries on the mechanical deformation properties of polycrystals (*ESN* 38-1:30-34 [1984]). Researchers at Warsaw have developed considerable expertise in using transmission electron microscopy (TEM) to study equilibrium and nonequilibrium grain-boundary structures in aluminum, copper, and austenitic stainless steel materials. J.A. Kozubowski and, more recently, W. Zielinski have developed TEM techniques for specifying the structural characteristics of annealed and deformed grain boundaries, including the use of Kikuchi line patterns for accurately determining adjacent grain orientations.

At Warsaw, TEM observations have been made of extrinsic grain boundary dislocations (EGBDs) contained within coincidence or low- and medium-angle grain boundaries after deformation. Apparently the EGBDs are not easily accommodated within the structure of such boundaries, except at temperatures where grain boundary diffusion can

occur, and this relates to the polycrystal strengthening effect of grain boundaries--even to the extent that changes in grain boundary state are proposed in some instances for aluminum, austenitic stainless steel, and similar materials to influence their mechanical properties more strongly than changes in grain size. Besides the TEM observations, measurements of grain textures, electrical resistivity, and stored energy have been made on annealed and deformed materials, including their recovery and recrystallization behavior. Current interest centers on the behavior at very small strains of ultrafine-grain-size materials produced by hydrostatic extrusion.

One important aspect of the ultrafine grain-size work which is being done on aluminum is shown in Figure 1 (Wyrzykowski and Grabski, 1982). The surprising observation of a pronounced yield-point behavior in tests at both 77°K and 293°K has been attributed to Lüders band propagation. A larger Lüders strain was measured at the higher temperature. Wyrzykowski and Grabski (1983) have reported that the ultrafine grain-size material showed a larger Hall-Petch (microstructural stress intensity) k value than was measured for less pure 99.7-percent aluminum materials. From measurements of different grain-growth behaviors observed in fabricating the two materials, the authors concluded that the Hall-Petch dependence is more strongly affected by differences in grain-boundary structure than by the purity difference. Hall-Petch results have been reported recently over a conventional range of grain sizes by Al-Haidary, Petch, and de los Rios (1983). At first sight, the results of the two studies seem comparable only if an effective strain of 1 to 2 percent is assumed to remain in the hydrostatically extruded ultrafine grain-size material.

Agreement with the Hall-Petch model for the general deformation behavior of polycrystals is provided by results of an *in-situ* TEM investigation of the early stages of plastic deformation in a austenitic stainless steel (Kurzydlowski, Varin, and Zielinski, 1984). Excellent TEM pictures were shown to establish three sequential stages of deformation behavior:

1. Movement of dislocations within the grain volumes;
2. Activation of dislocation sources at triple grain intersections and, separately, the formation of dislocation pile-ups against grain boundaries;
3. Propagation of slip across grain boundaries due to the stress concentrations from the pile-ups.

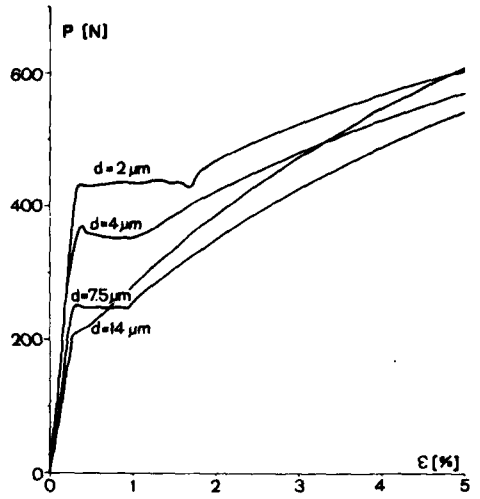

Figure 1. Tensile load, P (Newtons) versus elongation, ε (percent) for 99.99-percent aluminum rod materials of 3-mm diameter having different grain diameters, d; tests at 77°K and a strain rate of 1.66×10^{-4} s^{-1}.

Previously, Kurzydlowski and Varin (1983) have commented on their own model calculations showing that the stress concentrations at grain boundaries due only to elastic incompatibility are too small to cause general yielding. Kurzydlowski is carrying on with finite element and dislocation modeling of grain-boundary deformation behavior, including grain-boundary sliding at high temperatures. (Varin is now at the University of Waterloo, Canada.)

P.G. Zielinski is involved in rapid solidification studies. Specific heat, Curie temperature, and bend-test measurements on $Fe_{40}Ni_{40}Si_8B_{12}$ glass material were related to free volume and chemical clustering considerations (Zielinski and Ast, 1984b). The bend-test method has been applied to assessing the deformation behavior of $Ni_{75}Si_8B_{17}$ metallic glass (Zielinski and Ast, 1983). Outstanding scanning electron microscope (SEM) images were obtained of shear bands formed during *in-situ* bend testing. The shear band behavior has been successfully modeled with continuum-type pile-up calculations. In follow-up work, Zielinski and Ast (1984c) have described the deformation behavior of $Ni_{75}Si_8B_{17}$ glass material strengthened with WC or TiC particles. Figure 2 is an example of the SEM results obtained on this system.

The second phase TiC or WC particles, in the latter case up to about 7 volume percent, both stiffen the material and increase its yield strength. The

Figure 2. Shear bands, seen as narrow or broad white bands, on the bent tensile surface of $Ni_{75}Si_8B_{17}$ glass ribbon material stiffened and strengthened with 5 volume percent of TiC particles.

extent of plastic deformation is increased as well. Apparently, the strengthening can be accounted for on a Hall-Petch basis if the effective grain size is equated either to the mean free path between particles or their average separation, though the former distance seems to give more meaningful results. Thermal stresses coupled with pile-up stresses were judged to be important in distinguishing between the greater strengthening effect of WC as compared with TiC particles. The thermal stress effect has been used to explain the observation in Figure 2 that a number of the TiC particles are cracked by shear bands. This consideration has been discussed as well by Hahn and Armstrong (1982) for the general effect of inclusions potentially embrittling cleavage-prone materials. Of interest, too, is the novel modification of the melt-spinning method developed by Zielinski and Ast (1984a) for injecting the 2- to 3-micron TiC or WC particles into the melt puddle with a high-velocity helium jet. Zielinski is continuing work on the process.

Thermal stress considerations relate to interests at the High Pressure Research Center (HPRC) of the Polish Academy of Sciences; S. Porowski is director of the HPRC. J. Jung of the HPRC has used high pressure as a tool to assess the crystalline perfection and plastic flow properties of a variety of materials, including alkali halide crystals (Jung, 1984) and silicon crystals

(Jung and Lefeld-Sosnowska, 1983). In the latter case, the application of pressures up to 12 kbar (1200 MPa) at temperatures of 573°K to 1473°K for dislocation-free silicon has led to post-pressurization observations by x-ray topography of the strain fields of previously invisible amorphous SiO_2 particles. The work is important. Jung has several papers in press in *Philosophical Magazine* on "High Pressure-Induced Defect Formation in Silicon Single Crystals: I, Characterization of Defects and Conditions of Their Creation" (with Lefeld-Sosnowska); and "II, Mechanism of Stress Field Formation at Precipitates." Lefeld-Sosnowska is at the University of Warsaw Institute of Experimental Physics, where considerable research is being done on x-ray topography in connection with the dynamical theory of x-ray diffraction. Jung and Gleichmann (1984) have done combined x-ray topography and TEM work on high-pressure-induced macroscopic plastic flow due to otherwise unseen inclusions, scratches, and cracks in supposed defect-free silicon. Gleichmann is at the Institute of Solid State and Electron Microscopy of the East German (GDR) Academy of Sciences, 402 Halle/Saale, Weinberg 2, GDR.

W. Łojkowski at the HPRC plans to use high pressure as a tool to study grain-boundary diffusion processes--especially in connection with Grabski's proposal that dislocation movement in the grain boundaries can be appreciably enhanced by diffusion processes. Łojkowski has been involved with the TEM studies of dislocations in the grain-boundary interfaces. It is hoped that the measurements of pressure-dependent grain-boundary diffusion will give activation volumes which can be related to the mechanisms of atomic migration on the boundaries, even connecting with dislocation processes. Łojkowski's doctoral thesis dealt with the free rotation of randomly distributed silver microspheres (2 to 20 μm in diameter) during their sintering onto a single crystal silver substrate. The idea that the microspheres should rotate into positions giving low-energy grain boundaries between the spheres and substrate was attributed to P.G. Shewmon (Department of Metallurgical Engineering, Ohio State University).

A major connection between the HPRC and the Institute of Materials Science and Engineering is that the hydrostatic extrusion work used to produce the ultrafine grain-size materials has been done with HPRC-manufactured "Unipress" equipment. Multiple-stage gas compression is used to reach 30 kbar (3000 MPa). Early HPRC work on hydrostatic extrusion was done by L. Styczyński, W. Pachla, and Porowski, who investigated with S. Wojciechowski at the institute the influence of extrusion ratio on the microstructures developed in copper and aluminum materials. Differential scanning calorimetry measurements were used to sort out the concurrent and post-extrusion recrystallization behavior. Recently, Pachla and Styczyński (1984) have reported results on copper using the Unipress HEA 10 hydrostatic extrusion apparatus. Pachla is now on leave with B. Avitzur at Lehigh University; Styczyński is managing the Unipress extrusion facility.

An interesting outcome of the HPRC extrusion work is that a semiprivate manufacturing company has been set up by Porowski, with government support, to extrude cored soldering wire using Unipress machinery. HPRC and Institute of Materials Science and Engineering staff members who were involved in developing the equipment and wire processing are shareholders in the company. Other private investors are involved also. Porowski has employed a PhD economist, J. Macieja (Institute of Economic Sciences, Polish Academy of Sciences), to help with the company development. Contracts for the new company were signed in April 1984. Porowski and Grabski pointed out that such a practical development has occurred because of reductions in government support of research--and they gave much credit to the staff for the enthusiasm with which the new kind of activity has been undertaken.

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5/30/84

UNDERSTANDING THE FRACTURE OF METALLIC MATERIALS: UNIVERSITY OF CAMBRIDGE

by Kenneth D. Challenger.

Last month, *ESN* described the methods that the UK's Central Electricity Generating Board (CEBG) uses in assessing structural integrity--i.e., resistance to catastrophic fracture (*ESN* 38-8:432-434 [1984]). One of the main weaknesses in the CEGB method, and for that matter in all such assessment methods, is the inability to predict a steel's transition from ductile to brittle behavior. This weakness in the various methodologies is due to an insufficient understanding of the basic fracture mechanisms, specifically those factors that influence the change from ductile to brittle behavior.

Dr. John Knott and his students in the Department of Metallurgy and Materials Science, University of Cambridge, have been investigating the fracture mechanisms of metallic materials for many years. Their work has significantly contributed to the current understanding of both brittle and ductile fracture mechanisms and the factors that lead to the transition (frequently encountered with steel structures) from ductile to brittle fracture.

Currently Knott's research group consists of Knott, two postdoctoral students, one visiting professor, and about nine graduate students. Financial support for their research comes from both industrial and governmental sources. With this type of support he is able to perform the basic research necessary to advance the understanding of fracture mechanisms, but is required by his industrial sponsors to focus on current or anticipated problem areas. This is the strength of his research--supporting the advancement of technology through good fundamental research. He is pursuing an understanding both of fracture mechanisms and of fracture-mechanics concepts.

One example of their basic research efforts concerns one-step temper embrittlement of steel, often called 350°C embrittlement. The low-temperature fracture toughness of high-strength quenched and tempered steel is degraded by the steel's exposure to temperatures around 350°C. It is generally agreed that this loss of low-temperature fracture resistance is due to the segregation of impurity atoms such as P, S, and N to prior austenite grain boundaries. The segregation of these elements lowers the cohesion of the grain boundary, which promotes intergranular fracture (a low-energy fracture mechanism). In the embrittling temperature range the precipitation and coarsening of cementite (an iron carbide) also occurs, which is also thought by some to contribute to the degradation of fracture resistance.

The role of the carbide precipitation and coarsening is the subject of a current investigation by P. Bowen and Knott. Two possibilities exist: since the embrittling species are essentially insoluble in the carbides, they are rejected as the carbide grows. This

rejection of impurity atoms may exacerbate the effect of the segregation that occurs during the austenitizing treatment. The other possibility is that the carbides assist in the nucleation of microcracks, the propagation of which leads to fracture. A533B steel (used for nuclear-reactor pressure vessels) is being used for this study.

Phosphorous segregation to prior austenite grain boundaries has clearly been confirmed to play a major role in the embrittlement. The researcher's results on the effect of the carbide reactions on the embrittlement indicate that both possibilities (i.e., impurity rejection and assisting crack nucleation) do, in fact, occur. If prior segregation is low (low impurity concentration and high austenitizing temperature), then carbide coarsening that occurs in the embrittling temperature range reduces the fracture toughness, but without any significant increase in the amount of intergranular fracture. This reduction in fracture toughness is presumed to be due to carbide cracking during stressing, which assists crack initiation in the surrounding metal. However, when significant prior segregation exists in the austenite (high impurity concentration and low austenitizing temperatures), exposure to the embrittling temperature range reduces the fracture toughness due to a large increase in the amount of intergranular fracture. This is interpreted as evidence to support the other possible fracture toughness degradation mechanism: impurity rejection as the carbides coarsen.

One example of Knott's more applied fracture programs is a research project by Christine You. A primary concern in the integrity analysis of pressure vessels is whether the vessel will leak, warning of impending disaster, before it fractures catastrophically. This involves a consideration of the service conditions and the fracture toughness of the material. Another factor to be considered is the size and shape of a presumed flaw in the structure; the most likely flaw has a "thumbnail" geometry. Current fracture-mechanics concepts would predict that the flaw will grow in both the depth (through the wall thickness) and the circumferential (spreading out around the circumference of a cylindrical vessel) directions at the same rate. Thus, if the critical crack size (that which will grow catastrophically) is exceeded in the circumferential direction before the crack has penetrated the wall thickness (causing a leak), catastrophic failure of the vessel will occur without warning. You and Knott have shown that the thumbnail surface flaw propagates through the thickness easier than it spreads circumferentially. In analyzing their experimental data and carefully studying the fracture surfaces of broken test specimens, they find that the proximity of a surface in the circumferential direction allows a relaxation of the constraint at the crack tip, which in turn reduces the degree of triaxiality causing the slower growth in the circumferential direction. This has major implications in pressure-vessel design, because a "leak before break" is more likely to occur than predicted by current fracture-mechanics concepts.

These are only two examples of the many programs under Knott's direction. His other research programs include stress-corrosion cracking mechanisms in aluminum alloys; the behavior of "short" cracks (100 μm) when subjected to cyclic loads--they appear to be near a valid explanation based on crack closure considerations for why "short" crack behavior cannot be predicted by theories developed for long cracks; mechanisms for strain localization in aluminum alloys; fracture mechanisms in steels with mixed microstructures--it is critical to know not only the amount of each microconstituent, but also its location relative to the crack front; strain aging as related to the low toughness that exists in the first, or root, weld pass in a multipass steel weld; temper embrittlement; prestressing effects on fracture resistance; and creep-fatigue interaction with both ferritic and nickel-base alloys--the researchers have a fine elevated-temperature vacuum testing facility.

In summary, Knott's research is very relevant to the US Navy; it has made and will continue to make very significant contributions to the understanding of fracture mechanisms in metals, and it complements the research on-going at the Naval Research Laboratory and the David Taylor Naval Ship Research and Development Center.

5/30/84

OCEAN SCIENCES

CHANGES FORECAST FOR UK OCEANOGRAPHY

by Robert Dolan. Dr. Dolan, formerly at ONR, London, is Professor of Environmental Sciences at the University of Virginia.

The UK is considering several changes in its support of academic and government programs in oceanography. For the past several months there have been rumors of changes. The following is a summary of what I have heard about these changes.

First, the Institute of Oceanographic Sciences (IOS) facility at Taunton will be closed, and the programs and staff will be moved. At one time I heard that IOS Taunton would be moved to IOS Wormley, then more recently that part of its staff may be moved to IOS Bidston, and part to Wormley. Somewhat less definite, but still under consideration, is a plan to move IOS Bidston to Wormley and thus consolidate all of IOS at one place; but this would probably be well into the future.

Second, government support for academic oceanography may be concentrated at two universities rather than the present four. Support for the programs at the University of Liverpool and at the University College of Swansea, Wales, will probably be reduced significantly or discontinued, and all new oceanographic resources, including faculty and staff, will be concentrated at the University of Southampton and the University College of North Wales at Bangor. The goal, it is rumored, is to bring Southampton and Bangor up to a faculty of 16 each. Additional resources will be made available so that the programs at these two institutions can "achieve an international level of recognition and competition." To quote one source, the objective is to "make them among the most advanced in the world."

There are at least 75 institutions in Great Britain with some kind of program of instruction or research in marine science; however, IOS dominates the scene. Funded and managed by the Natural Environment Research Council (NERC), IOS has over 350 employees in three locations. The program at the main laboratory in Wormley, south of London, concentrates on the deep oceans and has programs in physical, chemical, biological, geological, and geophysical oceanography. The branch at Bidston concentrates on sea level, waves, tides, and storm surges, with highly competitive work on modeling the dynamics of shallow seas (*ESN* 38-4:199-202 [1984]). The branch at Taunton inventories and analyzes statistical data on ocean waves around the UK for coastal engineering and for planning purposes. The Taunton research staff also studies the dynamics of sediment movement along the coast and in shallow shelf seas. A small contingent of IOS is located at the Laboratory of the United Kingdom Marine Biological Association in Plymouth, where they carry out physical studies for the biologists and studies of the dynamics of shelf seas around the UK--including fronts, residual currents, and the distribution of bottom stresses. An NERC division at Barry, Wales, operates the fleet of UK oceanographic research ships.

The universities at Liverpool, Southampton, Bangor, and Swansea have full-scale departments of oceanography with research and teaching activities. Probably the best known is at Liverpool, which concentrates on physical and chemical oceanography. However, reductions and changes in staff have had an impact in recent years. The department at Southampton has programs in physical, chemical, geological, and biological oceanography and marine geophysics. Bangor has physical oceanography, with programs in physical and chemical oceanography and marine geotechnics, as well as a department of marine biology. The program at Swansea is largely devoted to marine geology, but recently has branched out into physical, chemical, and biological oceanography. The other, smaller university programs in the UK are mostly based on one to four staff members, who usually specialize in one particular branch of oceanography.

6/14/84

MARINE AND COASTAL RESEARCH IN GREECE

by Robert Dolan.

In general, these are not good times for marine and coastal research in Greece--or in most of Europe and the Middle East for that matter. The economic recession is still alive and well in most of the countries I've visited. Government support for research is being cut almost everywhere. Staffs are being reduced, facilities are not being updated, and greater and greater emphasis is being placed on applied research. Problem solving is the key to research in Greece at this time. I recently spent a week in Athens visiting the main centers of marine and coastal research; the scientists I spoke with expressed little optimism. These are times of entrenchment; people consider themselves fortunate to have positions in research.

Four years ago, Wayne Burt wrote a summary of marine research in Greece

(*ESN* 34-7:346-351 [1980]). This article is an update of Burt's, with the addition of information on the coastal engineering program and research facilities at the National Technical University in Athens.

The Greek Hydrographic Service

My host at the Greek Hydrographic Service (GHS) was Mr. B. Roufogalis, head of the oceanography section. GHS is responsible for supplying the Greek navy with bathometric and oceanographic data. To do this, they use three oceanographic ships, about 20 civilian employees, and several naval personnel. The program at the GHS has changed very little since Burt's visit. They have added a new 90-m research ship, the *Phytheas*; initiated a new computerized oceanographic data bank; and updated the computational facilities in their cartographic division.

The Institute of Oceanographic and Fisheries Research

Dr. Alexandros Bousoulengas is the director of the Institute of Oceanographic and Fisheries Research (IOF), the largest institute for marine research in Greece. There are 33 professional scientists and 37 technical and support staff. These numbers have remained stable over the past several years. The IOF research program is focused on coastal areas, including pollution studies, fisheries research, freshwater ecology, and marine geology.

The geology division, which includes four full-time scientists and several graduate students, is working in three areas: coastal geology and marine archaeology; general sedimentation, including erosion of beaches due to human activities; and marine geology of the Aegean Sea. At present the geology team is struggling to establish a database of basic information. For example, there are no maps of marine sediment types or seabed topography for the waters around Greece, and the old British bathometric charts are still in use.

Given the serious pollution and erosion problem in Greece, the marine geologists of IOF have been strongly encouraged to concentrate on coastal problems, rather than on more basic marine research. Work in the Aegean on plate tectonics will not begin, I was told, for at least 3 years--about the expected time for delivery of a new IOF research ship.

The biological program at IOF concentrates on pollution. Untreated domestic effluents are routinely discharged directly into the sea around Greece. Athens alone, for example, releases 500,000 m^3 of untreated sewage per day into the Gulf of Saronikos. The underwater sludge field that has resulted has expanded out into the bay more than 3 km since 1972, and it's growing every day. The IOF researchers are monitoring pollution, and they are establishing the residence times or flushing rates for the bays along the Greek coast. Their results suggest that the natural water exchange in the bays is very slow, so their capacity to transport waste is low. Consequently, some of the Greek coastal waters are among the most polluted in the world, especially the waters adjacent to Athens.

The goal of the fisheries research program is to help in the development of a commercial fish-farming industry in Greece. The two researchers that I met at IOF are investigating the potential use of various saltwater species and are doing research on the feeding of rainbow trout. The rainbow trout are "farmed" in the mountainous areas of Greece and sold mostly to restaurants in Athens. The problem is that the food for the farm-reared rainbow must be imported, so the IOF researchers are trying to develop a suitable fish food from Greek food by-products or waste.

Coastal Engineering at the National Technical University of Athens

The Technical University of Athens has an active program in coastal and marine engineering. My host during this visit was Dr. C.I. Moutzouris, a senior lecturer in the Department of Civil Engineering.

The department is moving from the original campus in central Athens to new facilities in the foothills overlooking the city. The new construction includes a very large indoor laboratory with a wave flume and wave (model) basin, and plenty of room for expansion. The only problem I see is support for service, maintenance, and small-scale modifications of the experimental facilities. However, the facilities are among the best I've seen in Europe.

In addition to laboratory research on waves, breakwaters, and other coastal defense works, the coastal engineers at the Technical University provide advice and consultations to local authorities on coastal erosion and pollution problems. This includes field projects similar to those conducted in the US. For example, there is a serious problem with shoreline and beach erosion along the coast of the Gulf of Cornith, a highly developed resort area. The problem, as outlined to me, is classic. Farmers inland from the coast dam for irrigation the streams flowing to the sea, thus cutting off the main supply of

beach sediment. Then as shoreline erosion threatens the resorts, the individual owners build jetties and groins to stop the movement of sand along the coast. In addition, several marinas have been constructed; these only compound the problem, causing some places to suffer more serious erosion than others. The engineering solutions depend on the specific site. Moutzouris is trying to pull together data for a regional plan that will be acceptable to the local authorities and to the individual property owners. He's not optimistic because the Greeks are highly individualistic, he said; so those with stable beaches will be unlikely to agree to any change.

Moutzouris and his colleagues at the Technical University have organized the Symposium on Maritime Structures in the Mediterranean to be held in Athens from 17 through 21 September. The meeting is to focus on coastal and marine structure in low tidal and low wave energy environments.

For information on the availability of the proceedings contact:

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6/20/84

NORWEGIAN HYDRODYNAMICS LABORATORIES SUPPORT OFFSHORE OIL INDUSTRY

by Chester McKinney. Dr. McKinney, formerly at ONR, London, is Senior Research Scientist at Applied Research Laboratories, The University of Texas at Austin.

Exploitation of the North Sea oil field is making Norway a rich country with essentially no debt and a budget which is in the black. Furthermore, the potential for future production in the Norwegian sector of the field is considered to be enormous. The impact of the offshore petroleum activity on Norwegian research and development programs at universities, government laboratories, nonprofit private R&D centers, and industry is very evident and widespread. Offshore oil is the name of the game in Norway, a country with much unspoiled wilderness, a huge coastline (if one counts the fjords), and only about 4 million people. As one would expect for a country with such a long coastline relative to total area, Norway has a long history of ocean research, and the level of activity is increasing, with the emphasis being on solving problems related to offshore production platforms, drilling platforms, underwater pipelines, and supporting ships.

One of the major research establishments is the Norwegian Hydrodynamics Laboratories (NHL) in Trondheim. NHL is a joint venture of the Ship Research Institute of Norway and The Foundation of Scientific and Industrial Research at the Norwegian Institute of Technology. Both of these institutions have close ties with the University of Trondheim. NHL, whose director is Dr. Havard Berge, is organized into two major divisions, the Ship and Ocean Laboratory and the River and Harbour Laboratory, but the two labs are closely integrated. The research program is very broad-based and includes laboratory research, at-sea measurements, and theoretical work.

One of the newest and most impressive laboratory facilities is the Ocean Basin, which is used for studying basic as well as offshore problems. Wind, waves, and currents can be generated to simulate the environmental conditions for a wide range of models of fixed and floating structures. The basin has a length of 80 m, a width of 50 m, and a variable depth up to 10 m. Maximum current velocity is 0.2 m/s. A hydraulically driven wave maker along one of the 50-m sides can generate regular and irregular waves with a height of 0.9 m and periods of 0.8 s and above. A wave maker along one of the 80-m sides is composed of 144 individually controlled and electrically driven flaps and can generate waves up to 0.4-m high with periods of 0.6 s and above. Both wave makers can be controlled by computers or by programs stored on magnetic tapes. The combinations of the two sets of flaps can produce a very wide range of wave spectra and directions. The basin has been used extensively for testing offshore platforms, both fixed and semisubmersibles, but it also is used for measuring the responses of surface ships to high seas and winds. A major recent project was to test the guyed type of tower for use in water depths of 200 to 600 m. A 50:1 scale model was tested in the basin for a scaled water depth of 350 m. Waves equivalent to 30-m full scale were generated for the tests. This work was done under a contract with Brown and Root (US) and was sponsored by 13 oil companies.

A current project of considerable interest is the generation of two- and three-dimensional deterministic "freak" waves and the study of the effects of such waves on offshore structures and ships. A freak wave is a single, very large, plunging, breaking wave which is caused by a focusing of other waves of much more modest amplitudes. In the basin, freak waves of a specified type can be generated on a repetitive basis. One of my hosts on a recent visit to NHL was Dr. Soren Peter Kjeldsen, who has published a number of papers and reports on his work with freak waves, which includes both theory and basin experiments. He feels that freak-wave response may be a better way to test structures than using a long sequence of random waves. The latter are used to statistically predict the height of the "100-year wave." Based on meteorological data and long-term measurements, the largest wave that can be expected in a 100-year period can be predicted statistically. For example, a 100-year wave of 20-m heights would occur in a region where for 60 percent of the time the significant height would be less than 2 m. At present, the design wave height is 30 m for offshore structures in the North Sea. If this is too small then catastrophic losses may result, but if it is too conservative the construction costs are unnecessarily high (see also *ESN* 38-4:199-202 [1984]). The stakes in estimating wave spectra are high and can well justify high-quality research. The evidence accumulated at NHL has led the staff to conclude that in many instances freak waves can occur much more frequently than the 100-year wave. NHL appears to be a leader in the area of predicting and generating freak waves in a laboratory environment. Researchers have developed an analytical theory which takes into account the observed nonlinear dispersion of wave solitons. Linear wave theory fails to predict the outcome of the experiments. There is a significant wave-wave interaction when wave components are near the breaking point. These interactions lead to the generation of violent plunging breakers in deep water. The amplitude is more than the sum of the component waves, and the wave steepness can exceed significantly the theoretical limiting steepness of steady-state nonlinear waves. This explains the often-observed very short periods of freak waves.

Another major facility is a complex of towing tanks. The longest tank can provide a length of 260 m, a width of 10.5 m, and depths of 10 m for 85 m and 5.6 m for 175 m. The carriage can support 20 tons and can travel at speeds up to 12 m/s. The tow tank facility has been in operation since 1958 and over 1500 ship models have been tested. In the longest tank, waves up to a maximum of 0.9 m can be generated with periods from 0.8 to 5 s. The wave spectra are computer generated, using 100 sine components.

Another type of tank is known as a wave channel. One example is a tank 78-m long, by 3.8-m wide by 1.0-m deep. It is used primarily for studying breakwaters, beaches, pipelines, and other structures. The wave spectra are generated by a flap unit and by an air stream passing over the water surface (at speeds up to 10 m/s).

Yet another facility is a 3000-m^2 hall, which is used to model rivers, navigation channels, breakwaters, hydro power plants, and moorings. Types of studies include sediment transport, river hydraulics, ice flow, and waterborne pollution.

An entirely different type of flow facility is the cavitation tunnel, used primarily to study propellers, especially in regard to cavitation. NHL has two such tunnels, with the largest having a working section 2.08-m long by 1.20 m in diameter. The maximum water velocity is 18 m/s, and the maximum propeller speed is 3000 rpm, driven by a 300 hp motor. A wide range of hydrodynamic, acoustic (up to 160 kHz), and cavitation characteristics can be measured.

Not all of the pressing offshore problems can be studied in a laboratory environment--and seabed scouring is one of them. Scouring occurs almost always when some artifact is placed on the floor of the ocean where there are currents. And in shallow waters there are nearly always currents, due either to steady transport of the water or to oscillations caused by the effects of surface waves. Two of the primary artifacts of offshore oil work are pipelines and fixed platforms. These objects cause local changes in the current patterns; and, if the ocean floor is sandy, local scouring will occur. The research goal is to understand the physics of the scouring process and to devise techniques for minimizing such action. Pipelines can be buried (usually at significant costs), but the same solution does not apply to the legs of fixed platforms. Protection against scouring or erosion usually involves either attenuating the currents around the structures (absorbers) or making the transition from the sand floor to the structure less abrupt. Scaled model experiments in the laboratory are of some value both

in understanding the processes and in evaluating cures, but they cannot provide all the answers. This is because it is not feasible to scale the sizes of the sand particles; but if this is not done, the results are suspect and difficult to use for extrapolation to full-scale structures. In brief, the relation between scour in model scale and full scale is not clear. In order to have better data, NHL currently is conducting offshore experiments. Clearly, the problem is an important one.

Working in the real ocean is not unusual for the NHL staff. They have done extensive surveys of the Norwegian coastal environment. These surveys include measurements of waves, currents, temperature, salinity, tides, bottom structure, and weather. Once again, these surveys support the offshore program, so the types and locations of surveys are designed to meet those applications.

At present NHL is making continuous measurements at three sites along the coast (along a 1400-km baseline). Typical storm-wave heights are 20 m and propagate at speeds up to 90 knots. For a wavelength of 350 m, bottom interaction extends at least to 175-m depths. The Norwegian coastal current is about 1 knot, but close to shore it may be much higher.

The offshore oil operations in the North Sea have pinpointed new and important problems in a harsh and complex environment. The economics of the situation are such that significant funding is available to attack these problems, and Norwegian institutions are responding to the challenge. The research effort, largely applied in nature, will benefit the oil industry. But at the same time the body of basic knowledge about the North Sea environment will be expanded enormously.

6/19/84

WINDS AND WAVES

by Robert Dolan.

Although waves more than 30-m high have been reported, a gauge-measured wave of such dimensions is rare. Figure 1, presented at the Symposium on Wave and Wind Climate (London, April 12 and 13), shows a gauge-measured, 82-foot wave (26 m) along with several others with heights in excess of 60 feet (20 m) with 10-second periods! To someone at sea, these would look like walls of water. The topics covered at the Wave Symposium included big waves, freak waves, wave climates, wave hindcasting, wave databases, and the importance of waves in ship design and ship routing. The *Proceedings* of the symposium, consisting of 10 papers, are available from the Royal Institute of Naval Architects, 10 Upper Belgrave Street, London SW1X 8BQ.

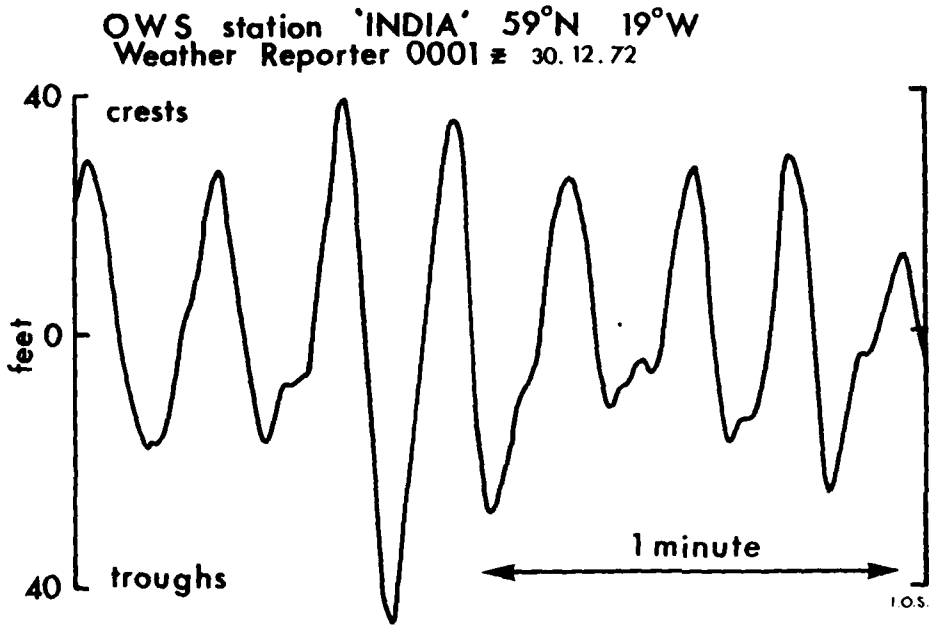


Figure 1. Extreme wave heights.

The Waves Symposium got off to an excellent start with an overview lecture by Susan L. Bales of the David Taylor Naval Ship Research and Development Center. Her paper, "Development and Application of a Deep Water Hindcast of Wave and Wind Climatology," summarized the history of the US Navy's use of and need for environmental data, and described the development over the past 10 years of the Navy's Hindcast Climatology (HCC) program. In my opinion it was the best paper presented at the symposium.

Bales pointed out that until the 1970s the US Navy seldom considered the natural environment in the design of its ships--after all, not many ships have been lost due to wave or wind action since 1944. However, millions of dollars are lost each year in repairs due to wind and wave damage. Consequently, today naval architects use sea state and wind data routinely in evaluating the performance characteristics of ship hulls. As one would expect, the three environmental factors that most influence ships are waves, wind, and rain. Waves are, by far, the most important factor to consider in ship design.

The fundamental question facing the scientist responsible for supplying wave information to the naval architects is: "Are there spatial and temporal patterns in sea state and are they predictable?" To answer this question the wave

climatologists need data--lots of it from lots of places. Unfortunately, only a limited number of wave-measuring devices have been operating for more than a few years. Therefore, indirect measurements are essential in establishing wave climates. Soon, however, permanent satellites will provide all the wave data the climatologists need, perhaps even more than they need or have computer capacity to process. But for now, wave "hindcasting" is essential for climate investigations, and wave forecasting is needed for predicting the sea state under which ships will operate.

Wave hindcasting and forecasting models are based on the assumption that there is a high correlation between wind speed and direction and wave characteristics over the ocean area (fetch) in question. Therefore, the model results depend on accurate wind data, which may not be available for open ocean areas. Consequently, the wave climatologists turn to the meteorologists for atmospheric pressures over the fetch areas, which they then translate into wind fields and then into wave fields. So the entire process depends on a stream of associations, with pressure and winds as the critical link. Present hindcasting models have developed from a simple desk-top analysis with order-of-magnitude skills to the current large-scale numerical models. Today the models are producing results that are highly correlated with actual gauge-measured waves. Table 1, developed from many years of hindcasting, shows the annual probabilities of occurrence for sea-state conditions in the northern hemisphere.

Table 1

Annual Sea State Occurrences in the Open Ocean Northern Hemisphere

Sea State Number	Significant Wave Height (m)		Sustained Wind Speed (Knots)*		Percentage Probability of Sea State	Modal Wave Period (Sec)	
	Range	Mean	Range	Mean		Range**	Most Probable
0 - 1	0 - 0.1	0.05	0 - 6	3	0	–	–
2	0.1 - 0.5	0.3	7 - 10	8.5	5.7	3 15	7
3	0.5 - 1.25	0.88	11 - 16	13.5	19 7	5 15 5	8
4	1.25 - 2 5	1.88	17 - 21	19	28 3	6 16	9
5	2.5 - 4	3.25	22 - 27	24.5	19 5	7 16.5	10
6	4 - 6	5	28 - 47	37.5	17.5	9 17	12
7	6 - 9	7.5	48 - 55	51.5	7 6	10 18	14
8	9 - 14	11.5	56 - 63	59 5	1 7	13 19	17
>8	>14	>14	>63	>63	0 1	18 24	20

*Ambient wind sustained at 19.5 m above surface to generate fully-developed seas To convert to another altitude, H_2 apply $V_2 = V_1(H_2/19.5)^{1/7}$

**Minimum is 5 percentile and maximum is 95 percentile for periods given wave height range.

Table 2

Comparison of Calculated and Measured Extreme Wave Heights

10 Years Hindcast	Significant Wave Height, M					
	Hindcast	R = 1	R = 10	R = 25	R = 50	R = 100
North Atlantic	19.5	19.0	21.8	22.9	23.7	24.5
North Pacific	19.5	19.9	22.4	23.2	24.3	25.0
Station India (Grid Point 128)	17.8	16.1	18.6	19.6	20.3	21.0
Station Papa (Grid Point 184)	18.1	16.8	19.2	20.2	20.8	21.5

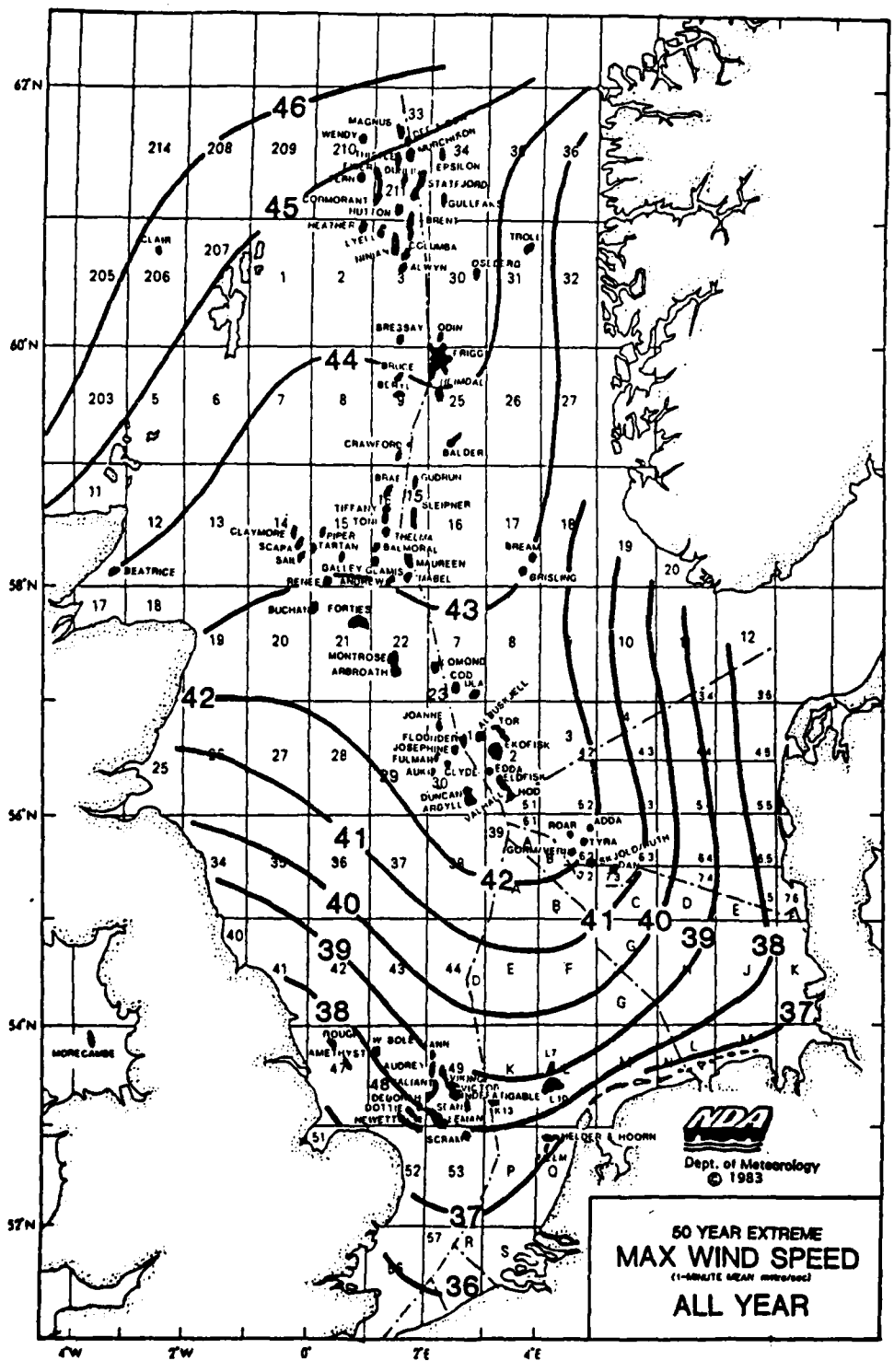


Figure 2. Fifty-year extreme maximum wind speed, North Sea; 1-minute mean, meters per second. (Reproduced courtesy of Meteorology Department, Noble Denton & Associates Limited, London.)

As indicated earlier, good-quality wave data for deep-water areas are available for only a few locations. However, it is expected that within the next decade, satellite sensing of wave height will revolutionize the offshore wave-climate field. Early instruments such as those carried on the GEOS-3 or SEASAT satellites have shown considerable promise; in fact, good data were

obtained from the measurements by GEOS-3, but it and SEASAT are no longer operating. Although SEASAT was operational for only a limited period in 1979, scientists have been able to make maps of SEASAT data that show the mean significant wave height over the the entire world during that period. There seems to be no immediate prospect of routine and cost-effective measurement of wave period or length from satellites, although the wave climatologists believe there may be a theoretical basis for a solution.

When it is possible to anchor wave-measuring instruments, but the location is too remote for direct radio transmission, wave data can be transmitted via an earth satellite back to base. This step should appreciably extend the areas over which wave data can be obtained. This is a possible solution to the problem of obtaining instrumental measured height, period, and spectral wave data from oceanic areas for use in calibration of the satellite data.

To help answer climatological questions more effectively, a computerized index of instrumentally measured wave data has been developed at the UK Institute of Oceanographic Sciences. The index includes geographical location, contact organizations holding the data, type of instrument, dates of operation, analysis procedures, data and presentations available, together with other information to enable potential users to assess the value of the data to their particular projects. In addition, the National Marine Institute, a private UK firm, in collaboration with the UK Meteorological Office is compiling a new wave-data atlas (see the note on page 514).

Let's return to the "freak waves" shown in Figure 1; these are measured waves, not hindcasted. However, the wave climatologists are beginning to use models to predict extreme values of sea state. For example, Table 2 shows the extreme hindcasts compared to those calculated by the application of order statistics and the Weibull probability distribution of the data (this method predicts fairly accurate extremes for large sample sizes). For the North Atlantic, for example, the hindcast extreme wave height is 19.5 m, while the Weibull prediction closely agrees at 19.0 m. For a return period of 100 years, the predicted extreme is 21.8 m.

One closing question: who needs wind and wave data? I have already mentioned the US Navy, and other navies are similarly interested. But today the offshore oil and gas industry is the biggest customer for wind and wave data. One of the papers presented at the symposium summarized the application of wind and wave information in the North Sea. Figure 2 is a sample map that shows the relationship between predicted maximum wind speed and the location of North Sea oil fields (for information about the *North Sea Environmental Guide*, see the note on page 513). These data, along with wave predictions, are then coupled with water depths and operational restrictions for different types of exploration and production rigs--essential information, considering that the investment in a deep-water rigs runs into the hundreds of millions of dollars.

6/14/84

PHYSICS

FRACTALS IN THE PHYSICAL SCIENCES

by Michael F. Shlesinger. Dr. Shlesinger is a Scientific Officer in the Physics Division, Office of Naval Research, Arlington, VA.

The workshop "Fractals in the Physical Sciences" was held at the École de Physique at Les Houches, France, from 19 through 30 March. It was organized by B. Mandelbrot (IBM), M. Mendes-France (University of Bordeaux), J. Peyriere (University of Paris-Sud), and M. Shlesinger.

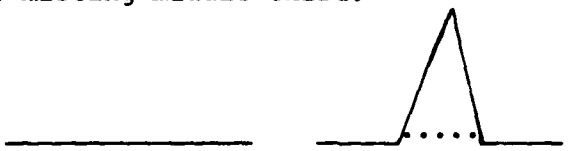
The attendance was limited to 60 participants, and the workshop was conducted in an informal atmosphere with a flexible agenda to allow for extensive discussions of topics which generated a high interest. The meeting was dedicated to the memory of Elliott W. Montroll (1916-1983), a distinguished scientist and former Director of Physical Sciences at ONR. A review of his scientific works and career was given by M. Shlesinger.

The word "fractal" was coined by Mandelbrot in 1975 to describe geometric structures which possess no characteristic size, but instead have features which behave in certain precisely defined ways when observed with finer resolution or scale: if a feature, on each scale, is observed upon the next finer resolution to be composed of N smaller features each scaled down by a factor R, then the geometric object is said to have a fractal dimension $D = \ln N/\ln R$ or $N = R^D$.

For example, consider a square of side s, and suppose the square itself is considered the "feature" of interest. That feature can be decomposed into $N = P^2$ little squares (features) of side s/P, each of which is the same as the original square (feature) except for being scaled down by a factor R = P. According to the definition, the square therefore has fractal dimension $D = \ln N/\ln R = \ln P^2/\ln P = 2$. Likewise, a line-segment feature has fractal dimension D = 1, and a cube feature has fractal dimension D = 3.

In light of the preceding examples, you might expect curves to have fractal dimension D = 1, areas fractal dimension D = 2, et cetera. Surprisingly, this need not be true for either theoretical or physical examples.

For a theoretical example, consider a "Koch curve"; this curve is formed as the limit of a sequence of broken-line curves. First, start with a single line segment of length unity. Second, replace that by N = 4 line segments of length 1/3--thus scaled by a factor R = 3--formed by replacing the middle third of the original segment by two segments forming an equilateral triangle with the now missing middle third.



step 1 step 2

For the third step, perform the previous process on each of the four segments obtained in the second step; continue this process. In the limit you obtain a continuous curve of infinite length and having fractal dimension $D = \ln N/\ln R = \ln 4/\ln 3 = 1.26$ approximately.

Physical Examples

Mandelbrot discussed a rugged coastline as a physical example of a curve with fractal dimension exceeding unity. The coastline's length will depend upon the resolution with which it is measured. In a finer resolution more details will appear, thus increasing the apparent length. If the resolution is Δ and $N(\Delta)$ is the number of times a ruler of length Δ must be placed end to end to cover the coastline, then the measured length L will be $L = \Delta N(\Delta)$. If $N(\Delta)$ scales as Δ^{-D} with D>1, then L will diverge as $\Delta \to 0$. However, $\Delta^D N(\Delta)$ will be finite, implying that the coastline is really a D dimensional object, where D does not have to be an integer. Various coastlines examined, in fact, do give values of D between one and two.

An analogy of this idea was discussed by P. Pfeiffer (University of Bielefeld) for determining the dimension of the rough surface of a catalyst. A number N(R) of planar molecules, each of area R^2, is used to form a monolayer on a catalytic surface. The experiment is repeated with a different molecule with a smaller area. If N(R) scales as R^{-D}, then the measured surface area will grow as R^{2-D} as smaller molecules with smaller R values are used. With this method, surface dimensions of 2.07 for graphite, 2.25 for carbon black, 2.79 for porous alumina, and 2.94 for silica gels are found.

Fractal shapes are also seen in everyday objects such as the surface of clouds, as reported by S. Lovejoy and D. Schertzer (Meteorologie National, Paris). An analysis of satellite data has shown that the projected area A of rain clouds (the samples varied over six orders of magnitude) varies with their perimeter as $P \sim A^{1.35/2}$ instead of the expected $P \sim A^{\frac{1}{2}}$ behavior. This implies that clouds have 2.35 dimensional surfaces. A theory in agreement with these findings was proposed by I. Procaccia (Weizmann Institute) and G. Hentschel (Massachusetts Institute of Technology [MIT]) based on the nature of turbulent diffusion in the atmosphere. The essential result was that the vortex structure is concentrated on a 2.6-dimension space and does not fill the full three-dimension space. That turbulence is not space filling results from the stretching of vortex tubes, which must decrease in cross section to conserve circulation. The tubes are folded on all length scales by convective motions in such a manner to avoid tube intersections (analogous to certain polymer problems), thus making it difficult for these tubes to fill all space. Incorporating these ideas into a generalization of Richardson's diffusion-like equation for the separation of a pair of neighboring points leads to a turbulent surface of a cloud with dimension near 2.35.

Another physical example of a fractal shape appearing in nature is the fracture surface of a metal broken by tensile or impact loading. D. Passoja (Union Carbide) discussed experiments where a fractured steel specimen was plated with nickel and polished parallel to the plane of the fracture. Islands of steel with fractal "coastlines" emerge and merge with increased polishing. This has been called the slit island technique. A coastline dimension of 1.28 is found. However, a decrease in the dimension can be found with aging.

Aggregates

Fractal shapes are also seen in electron microscope pictures of soot. The soot is a light, wispy figure formed by an aggregation of smaller particles. T. Witten (Exxon) discussed kinetic growth models which result in the formation of fractal objects. If the number of smaller particles N(R) inside a sphere of radius R scales as R^D, then the object is said to have dimension D. If D is less than three, say for an object in three dimensions, then this implies that the mass is distributed in a self-similar manner--i.e., clusters of clusters of clusters. The Witten-Sanders model of diffusion-limited aggregation generates fractal shapes of dimension D = 1.6 and D = 2.4 in two and three dimensions respectively.

In this model there is a fixed seed particle amidst diffusing particles. When a diffusing particle hits the seed, it sticks and is allowed no further motion (i.e., surface tension does not play a role). In this manner the original seed grows, but as a dendritic structure and not as a compact object, because bumps tend to grow as they have a larger surface area and thus are more likely to be struck by diffusing particles. This is the analog of the Mullins-Serkera instability, which leads to dendritic growth of a solid from a melt where the growth of the solid surface is quickest at the sharpest points on the surface. As these dendritic branches grow radially outward, they shield inner regions, thus not allowing the aggregate to become compact.

G. Hentschel (MIT) remarked how introducing rotational brownian motion of the aggregate would further favor the growth of long dendritic arms, because their end points would sweep out wide arcs and catch new particles before they have a chance to diffuse to more inner sites. His simulations showed that the aggregate dimension can approach unity as the rotational motion increases. Witten also examined the possible shapes resulting from a cluster-cluster aggregation as opposed to particle-cluster aggregation. A fractal dimension of 1.7 in three dimensions is found for cluster-cluster aggregations--independent of whether the clusters diffuse or move ballistically. These fractal structures can cover a large space with a little material. Such shapes can induce viscosity in fluid flows or clog filtration systems, as discussed by D. Houi (Institut de Mecanique des Fluides, Toulouse, France).

Treating a similar problem. R. Voss (IBM) discussed the growth of aggregates on a surface. Independent diffusing particles produced a cluster of dimension 1.7 up to a correlation length L, which depends on the fraction of surface sites initially occupied. At lengths larger than L, the cluster is two dimensional. Shapes reminiscent of electrochemical dendritic growths are generated. Y. Sawada (Tohoku University) discussed the pattern selection and stability of such shapes.

Percolation Clusters

The percolation cluster is an interesting fractal shape discussed by many lecturers. On an infinite square lattice, consider that bonds are present only with a probability p. For p small, an infinite cluster of connected bonds will not exist. However, a critical value of p exists (equal here to ½) for which an infinite cluster of bonds first appears.

The fractal dimension of this percolation cluster is 1.89, while that of its backbone (all deadends removed from the cluster) is 1.7. However, the fractal dimension does not describe fully the dynamics of physical processes concentrated on a fractal set. Consider the vibrational spectrum of a fractal object. The density of vibrational states will scale at low frequencies as ω^h, where h is D-1 for a euclidean object and can be quite different for a fractal one. The exponent h has been called the harmonic, spectral, and fracton dimension.

A sharp debate, still not settled, is to determine how many different exponents are needed to describe physical processes on fractal objects such as diffusion on, diffusion into, vibrations, refraction of light, and magnetic correlations. R. Orbach (University of California at Los Angeles [UCLA]) discussed the problem of diffusion or random walk on fractal lattices. The exponent h was shown to describe both the probability of a walker returning to its origin and the vibrational spectra. The fracton dimension h was found to be close to 4/3, independent of whether the percolation cluster was generated in two or three dimensions. This universality was a surprise, and it still has not been fully explained. Orbach examined the far-infrared vibrational spectra of a number of glasses and amorphous Ge, and found results consistent with the notion of fractal structure on small scales.

S. Alexander (Hebrew University) and Orbach conjectured that h = 4/3 for all fractals generated in random fashion. The conjecture works well in high dimensions, but A. Aharony (Tel-Aviv University) argued that it breaks down

for fractal dimensions less than 2.1. His ideas were based on considering the exponents of the conductivity of the lattice and finding inconsistencies if the 4/3 rule was correct. Aharony also gave a review of percolation theory.

Other Issues

R. Rammal (University of Pennsylvania and Centre National de la Recherche Scientifique, Grenoble, France) discussed in more detail the statistics of random walks on fractal objects. He showed that for a lattice, the number of new sites visited after N steps scales as $N^{h/2}$, and thus the meeting of walkers (reactions) is governed by the spectral dimension h. S. Havlin (US National Institutes of Health and Bar-Ilan University) constructed nonrandom fractal shapes called Havlin Carpets with independently varying fractal and spectral dimensions which are useful for examining the relative importance of these dimensions on physical processes.

Aharony and Y. Gefen (Institute for Theoretical Physics, Santa Barbara, CA) studied the magnetic phase transition of spins on fractal lattices such as Koch curves and Sierpinski gaskets and carpets. On gaskets with finite ramifications (only a finite number of bonds need to be cut to isolate any part of the lattice), a phase transition only occurs at zero temperature. On carpets with infinite ramification, a finite critical temperature is realized. However, the connectivity and lacunarity of the lattice still affect correlations of spins near the critical temperature.

The general problem of transport in disordered media was discussed by E. Guyon (École Supérieure de Physique et de Chimie Industrielle, Paris), who called the topic MIAM, for milieux aleatoire macroscopic. The important problem of oil recovery as a flow of oil through water-containing porous rocks was addressed by Guyon and R. Lenormand (Schlumberger). The exerted pressure determines if the oil can enter a water-filled pore. At high-enough pressures, a percolation path for the oil is formed and a flow can be achieved. A. Le Mehaute (Compagnie Générale d'Électricité, France) described transport through a fractal interface, such as electron transfer in a battery with a porous electrode.

Transport in disordered systems can lead to a mean-square displacement of a random walker growing as t^h with h less than one. Regular brownian motion has h = 1. When this sublinear temporal behavior is due to long time intervals between motion (and not, say, to the particle following a fractal path), then such processes are said to be governed by a fractal time waiting-time distribution between jumps. This means that there is no characteristic time governing motion, but that the set of event times is self-similar. My presentation dealt with reaction kinetics governed by a fractal time stochastic process. For example, a fractional exponential lifetime distribution is found for an immobile species (frozen dipole) in the midst of many mobile (but governed by fractal time) species (pieces of free volume) which can combine with the immobile species. This is called the Williams-Watt law, and it governs dielectric relaxation in many amorphous materials.

B. Souillard (École Polytechnique, France) reviewed the theory of localization of electrons in MIAM with an emphasis on the possible fractal nature of the wavefunction near the origin. Similar results were presented by F. Axel (University of Paris-Sud) for the behavior of electrons in two superposed but incommensurate potentials.

F. Family (Emory University) discussed models of polymer configurations. He showed that under mild restrictions only three different types of structures would form. If the excluded volume effect was weak, collapsed structures with the euclidean dimension d equal to the fractal dimension D would form. If it was exactly compensated by screening, then $D = (d+2)/2$; and if the excluded volume effect was dominant, then extended structures of dimension $D = 2(d+2)/5$ would form.

In conclusion, many physical systems have been found to have fractal (self-similar) structure. The emphasis in this field has shifted from the dimension of the geometry to the nature of physical processes controlled by fractal structures--such as diffusion, diffraction, conductivity, screening effects, flow characteristics, and structure growth. New parameters such as the spectral dimension are found to govern these dynamic processes on fractals. Finally, though not discussed above, real-space renormalization-group techniques now play a major role in calculating these noninteger dimensions.

5/31/84

ISRAEL HOSTS METAL-HYDRIDES MEETING

by B.M. Klein and A.I. Schindler. Dr. Klein is a research scientist in the

Condensed Matter Physics Branch and Dr. Schindler is Director of Material Science and Component Technology at the Naval Research Laboratory, Washington, DC.

The Fourth International Symposium on the Properties and Applications of Metal Hydrides was held in Eilat, Israel, from 9 through 13 April 1984. Nearly 150 scientists from more than a dozen countries participated in the meeting, presenting papers on both basic and applied aspects of hydride research.

The opening session consisted of invited talks by Michael Pick, currently on leave from Brookhaven National Laboratory to JET (Joint European Torus, UK) Joint Undertaking, and by A. Nozik of SERI, in Colorado. Pick, a solid state physicist, described the importance of understanding the physics of hydrogen-metal interactions as they relate to fusion devices which use deuterium or tritium as fuels. He emphasized that the hydrogen flux onto the confining wall has direct effects on the plasma and its confinement. For example, hydrogen wall-plasma cycling affects the plasma density and temperature. The hydrogen flux also introduces impurities into the plasma through such processes as sputtering. This appears to be a ripe field for researchers studying hydrides.

In the second presentation of the opening session, Nozik gave a survey of present and future approaches to hydrogen production. The high price of conventional energy sources will undoubtedly be a constant stimulus for supporting such hydride research. He described the various techniques for producing hydrogen--e.g., synfuels, biomass conversion, solar cells, and thermochemical cycles.

L. Schlapbach (Swiss Federal Institute of Technology, Zurich) reviewed the status of x-ray and ultraviolet photoemission spectroscopy (XPS and UPS) measurements and comparisons with theory for a number of hydrides. Photoemission spectroscopy has proven to be a valuable tool for studying the physics and chemistry of hydrogen in metals. One of the more interesting results obtained recently has been the identification of the Pd-H bonding band location to be centered at approximately 8 eV below the Fermi energy of PdH, in agreement with theoretical predictions. Earlier UPS measurements had given this location several electronvolts higher, probably because of surface contamination (something the theoreticians don't have to contend with). Other experimental results discussed by Schlapbach included rare earth dihydrides (theory in fairly good agreement), $LaNi_5H_6$ (no theory), and Laves structure hydrides (theory needed here, too).

D. Zamir (Soreq, Israel) discussed nuclear magnetic resonance (NMR) measurements and how they, together with theory, can elucidate some of the fundamental properties of hydrides. In this area there is clearly a need for more theoretical input. While in the case of XPS and UPS measurements, comparisons can be made with routinely calculated theoretical electronic densities of states, theorists need to extract from their calculations additional wave function information to compare with NMR results.

F. Wagner and colleagues (Munich, West Germany) described their Mossbauer experimental studies of hydrogen diffusion in the hydrides and deuterides of V, Nb, and Pd. M. Mintz and A. Schultz (Israel) discussed time-of-flight measurements of direct atomic recoils produced by pulsed rare-gas ion irradiation of a solid surface, and showed how an analysis of the results gives important information about the surface chemistry and electronic structure of hydrogen-metal interactions. G. Sandrock (Ergenics, NJ) and P. Goodell (Inco Alloy Products Research Center, NY) discussed the engineering considerations of the cycle life of rechargeable metal-hydride devices.

A number of contributed theoretical papers dealt with the electronic structure of transition-metal dihydrides (Papaconstantopoulos and Switendick, US) and ternary hydrides (e.g., Mg_2FeH_6, by Gupta, France). Theoretical calculations for ternary systems are just coming to fruition, so Gupta's results generated a good deal of interest. She argued that the compounds with 18 valence electrons (e.g., Mg_2FeH_6, Ca_2RuH_6, $MgNi_2H_4$) are semiconductors, and that additional H absorption is inhibited by the cost in energy of populating states above the gap. Several experimental papers supported her results.

B. Lengeler (Jülich, West Germany) described x-ray absorption near edge structure measurements for a number of hydride systems. These measurements are related to the projected electronic density of states above the Fermi level (unoccupied) times a matrix element. Comparisons with theoretical augmented-plane-wave calculations for NiH were particularly impressive.

Two sessions were titled "NMR," with papers dealing with proton and muon Knight shifts and spin-lattice relaxation rates in a number of materials, such as PdH, TiH_2, ZrV_2H_x, and ZrH. Several experimentalists pointed out the need for closer collaboration between

theoreticians and experimentalists. Four sessions were devoted to applications; several papers dealt with hydrogen storage devices, and others covered a wide range of topics, including "Solving the Aircraft Fire Detection Problem" (D. Warren and colleagues, US).

A contributed paper which drew a lot of attention was presented by R. Griessen (A.H. Verbruggen, R. Griessen, and J. Rector, Amsterdam). He described measurements of the proton Hall effect in palladium and showed results which indicate that hydrogen in palladium acts as a particle of charge Z_H=+1, although it is completely (statistically) screened in zero field. There have been conflicting theoretical predictions about the magnitude of Z_H and about whether a "direct force" term exists. The experiment is a real *tour de force* of ingenuity and care.

Two sessions were devoted to materials, with several papers dealing with $LaNi_5$ and FeTi hydrides. Although no new breakthroughs were reported in the materials area, the combined theoretical and experimental efforts are gradually leading to a fundamental understanding of metal hydrides. Other sessions dealt with surface properties, and with thermodynamic, kinetic, and structural properties of metal-hydrogen systems.

This series of meetings is particularly fascinating because of the equal mix of basic and applied research. The next meeting will be in the Bordeaux region of France in about 2 years.

6/28/84

SPACE SCIENCE

THE EUROPEAN LOW GRAVITY RESEARCH ASSOCIATION

by R.L. Carovillano. Dr. Carovillano, formerly at ONR, London, is Professor of Physics at Boston College.

The European Low Gravity Research Association (ELGRA) was founded in 1979 to promote microgravity research. The objectives of ELGRA explicitly encourage European space research efforts in certain areas of physics and biology and in technology. Recent developments in ELGRA reflect the growing importance of the society and its role as representative and spokesman for the expanding European microgravity community. (See *ESN* 37-8: 336-337 [1983] for a report on ELGRA.)

ELGRA's membership increased more than 15 percent this past year and totals about 110. The members come from 12 European nations, Japan, and the US. Professor Luigi G. Napolitano (University of Naples, Italy) has been recently re- elected president of the society and continues to provide dynamic leadership. In other actions, Professor K.E. Klein (Institute of Space Medicine, German Aerospace Research Establishment [DFVLR], Köln) has been added to the Management Committee, and Professor H.I. Wolff became the UK representative on the National Council. A great deal of the scientific business of ELGRA is carried out by its eight working groups. The working groups and coordinators are:

- WG1: Crystal Growth and Metallurgy in Space, C. Potard (Atomic Energy Commission [CEA], Centre d'Étude Nucleaires de Grenoble, France)
- WG2: Microgravity Fluid Dynamics, R. Monti (University of Naples)
- WG3: Physiology and Medicine in Space, F. Bonde-Petersen (August Krogh Institute, Denmark)
- WG4: Space Biology, H. Planel (Laboratoire de Biologie Medicale, Toulouse)
- WG5: Radiobiology in Space, H. Bucker (DFVLR, Köln) and E. Schopper (Institut für Kernphysik, Frankfurt)
- WG6: Combustion in Space, J.J. Dordain (National Aerospace Research Office [ONERA], France)
- WG7: Education and Training, L.G. Napolitano (University of Naples)
- WG8: Critical Point Phenomena, D. Beysens (Saclay Nuclear Research Center, France) and R.H. Huijser (National Aerospace Laboratory [NLR], Amsterdam)

In meeting its objectives to promote microgravity research, ELGRA is actively engaged in space program planning and in sponsoring conferences. In an important recent development, ELGRA working groups have written a position paper on microgravity research that was unanimously endorsed by the ELGRA general assembly in January 1984. This report has been submitted to the European Space Agency (ESA) executive board, the delegates of ESA's member states, and ESA's Spacelab program board for consideration and possible adoption.

The ELGRA report makes both general and specific recommendations. General recommendations made in behalf of the European microgravity community are as follows:

1. The European effort should continue to be directed at improving the scientific understanding of basic

natural and biological microgravity phenomena occurring in the different domains of the life, materials, and fluid sciences with the objectives of: (a) fostering the progress of scientific knowledge, (b) promoting sound conception and future cost-effective developments of space production processes; and (c) ensuring the safe, productive, and prolonged permanence of man in microgravity environments.

2. To avoid shallow programming and duplication of efforts and to promote scientific yield, close cooperation and program coordination are encouraged not only among ESA member states but also between ESA and the US.

3. Viable and scientifically productive microgravity research programs require: (a) that flight opportunities with medium- and long-duration platforms be more frequent and more dedicated than presently available; (b) that the time interval between the selection and final definition of experiments and actual space flight be diminished; and (c) that flight opportunities with short-duration platforms be substantially increased.

4. Well-defined solutions of managerial problems such as the availability of adequate human resources or the existence of efficient decisional/operational structures are mandatory for the success of any research program, but much more so for microgravity programs--due to the infancy of the discipline.

5. Further, more consistent and widespread efforts should be made to promote microgravity research in both scientific and decision-making bodies at international and national levels.

6. European microgravity research should be conducted as mandatory programs.

Working groups considered ESA's current microgravity positions and developed recommendations in the four areas described below.

Crystal Growth and Metallurgy in Space. The working group observed that, in general, the fundamental aspects of microgravity are well represented in the ESA program, but applications are not. The following new facilities and concepts should be developed: (1) high-gradient directional furnace with possibilities for measurement and active process control; (2) positioning and shaping of liquid metal without contact; and (3) new measurement concepts and devices.

European reflight opportunities on Spacelab missions are unsatisfactory because facility concepts are old. An individual's experiment should be assigned the same priority as a multi-user experiment.

The working group expressed strong support for sounding rockets, support for airplane experiments, and weak support for a drop tower, though one such facility in Europe was recommended. Medium duration (1 hour to 1 day) is a common experimental requirement; many experiments are performed within this time frame.

The free flyer platform remains the best tool to reduce gravity fluctuations (Spacelab 1 suffered from such fluctuations). Platforms of limited duration, for instance 1 week to 1 month, were endorsed; experimenters seldom need 6 months.

More ground support in the form of technical help, documentation, and management is required from ESA.

Increasing the interest in microgravity research and opportunities within the materials science community is of prime importance.

Selection of the experiments for flight should be improved. The working group recommended that the first selection based on submitted forms remain open to revision until individual presentations by the experimenters are made. Documentation based on peer evaluation should be required for rejection of a proposal.

Microgravity Fluid Dynamics. In this area, the working group took the following action:

1. Endorsed the user support recommendations made at the April 1983 meeting on Materials Sciences Under Microgravity held in Madrid.

2. Expressed concern about whether the ESA phase-2 microgravity support staff is adequate to provide the required effort. The addition of a technical expert and a secretary to the staff was recommended.

3. Recommended that allowance for dedicated facilities be included in the fluid physics double-rack experiment.

4. Recommended that joint experiments be encouraged in ESA's Announcement for Experiments to reduce the number of similar individual submissions.

Physiology and Medicine in Space. The working group endorsed carrying out human experiments in space through the construction of Anthrorack, which will provide ample opportunity for physiological experimentation in space. The working group was waiting to hear of ESA's call for experiments for the Anthrorack mission and plans to consider that document when received.

Space Biology. This working group gave priority to the Biorack facility in the European retrievable carrier (EURECA) program; argued that there should be no conflict between the two life sciences facilities developed by ESA, Biorack and Anthropak; stated that future programs will require the development of an improved Biorack, with a larger volume available and compatible with equipment already developed; and urged that the reflight of Biorack scheduled for 1988 be done sooner.

Most of the considerations of the microgravity community refer to the Spacelab program and related programs such as EURECA. Microgravity research is one of the exciting areas of space science that can be carried out satisfactorily in low earth orbit and that uses the unique capabilities of the Space Shuttle. Spacelab--the special European contribution to the US transportation system--was developed and funded under the auspices of ESA at a cost of about $1 billion. To date Spacelab is second only to the rocket launcher Arianne in cost among ESA's programs and is the largest joint venture undertaken with US National Aeronautics and Space Administration (NASA).

Spacelab was launched on 28 November 1983 in a successful 10-day mission that involved the first European astronaut, Ulf Merbold. The mission was multidisciplinary, with more than 70 investigations in the life sciences, materials science, solar observations, space plasma observations, atmospheric science, astronomy, and earth observations. Spacelab included more than 3000 kg of instrumentation by scientists from ESA member states, the US, Canada, and Japan. ELGRA and Napolitano helped arrange the first European meetings on Spacelab results at a June 1984 symposium in Naples and a November 1984 meeting in Schloss Elmau, FRG. (See *ESN* 38-8:454 and 456 [1984]. October's *ESN* will feature a detailed article on the Naples symposium by Dr. Kenneth D. Challenger.)

Napolitano--whose field is fluid dynamics, including heat transfer, microgravity, and computational methods--made several interesting observations about the difficulty of doing space research. In 10 years of work from Skylab to the present, only about 32 hours of microgravity space experiments have been carried out. The infrequency of flight opportunity gives a space scientist few chances to learn from past experience and design new experiments.

The phase-2 microgravity program has now been presented to ESA delegates, but the contents will not be released until decisions have been made. A program recommended by Napolitano but not yet financed involves the effects of temperature gradients on fluids. A problem with such studies is that furnace operation tends to increase the average background temperature, and the temperature in the fluid-physics module intended to investigate the effects of gradients must be reduced to compensate for the effect; also, the module does not operate above a temperature of about 60°C. New facilities have been developed for experiments on second-phase inclusions in liquid matrices and critical point phenomena. The growth of solidification fronts and the presence of particles or bubbles in the gas-liquid interface can be studied. An entire double rack that contains all the surfaces for this type of fluid physics would be used for the experiment.

The US long-duration-exposure facility (LDEF) was launched in the April 1984 shuttle flight that also repaired the Solar Maximum Mission; the LDEF provided new opportunities for microgravity research. Although NASA invited and received foreign participation in the program, NASA's up-front funding requirements limited the European response, which did not involve ESA. Unless an explicit, bilateral, national agreement exists to accommodate foreign participation, Europeans find it difficult to cope both with NASA's procedures and with those of their own governments. Not surprisingly, ESA's procedures are normally more suitable for the European individual or group to respond to a mission announcement of opportunity. With ESA, initial approvals and selections are made purely on scientific grounds. With the ESA approval in hand, the individual may then solicit funding from his own government with the assurance that mission participation will take place. The ESA approval is, of course, a major asset in obtaining the required funding. With NASA, funding capability must be obtained prior to mission selection. Thus, in principle, a person with funds can be turned down on scientific grounds (which would certainly be embarrassing), or a selected person may be unable to raise the required funds.

For microgravity research, LDEF has the advantage of frequent shuttle access and retrieval, but the facility is basically a rack. In contrast, EURECA can accommodate and support a wide variety of microgravity experiments with subsystems similar to those on nonretrievable earth satellites. EURECA provides structural integrity, thermal control, power generation and distribution, data management, and attitude

control. The first EURECA flight is scheduled for a 1987 shuttle launch, with retrieval after 6 months. The basic structure for EURECA is provided by the German platform SPAS-01 (shuttle pallet satellite) that was tested and used on the 18 June 1983 shuttle flight.

5/29/84

TECHNOLOGY

UNDERWATER ACOUSTICS IN NORWAY

by Chester McKinney. Dr. McKinney, formerly at ONR, London, is Senior Scientist at Applied Research Laboratories, The University of Texas at Austin.

Acoustics activity in Norway is fairly large and quite widespread, being centered in several universities, a number of government, quasi-government, and not-for-profit institutions, and a few industrial companies. Some of the activity has been reported in past *ESN* articles, but the general nature of the work has been changing because of the impact of the Norwegian North Sea oil field. On a recent trip to Norway I visited several, but by no means all, of the groups involved in underwater acoustics; I will summarize their work this month and in October's *ESN*.

Simrad Subsea A/S, Horten

Horten, located about 65-km southwest of Oslo, has a population of only 12,000, but it is the home of some 40 electronics companies. It is known, at least locally, as the Silicon Coast. Most of these companies are very small; Simrad, with 190 employees, is one of the largest. For a long time, Horten was the primary Norwegian naval base, but about 25 years ago the fleet moved to Bergen and the navy influence is not great now. Simrad was founded in 1947 for the purpose of developing and producing sonars and depth sounders for the fisheries business. They early established an international reputation for building high-quality small sonars. At present they have sales and service offices in 56 countries, and about 50 percent of sales are outside Norway. Almost 50 percent of the shares of the company are foreign owned. About 5 years ago they got into the offshore business with the production of precision underwater-acoustic-positioning equipment; and this type of work now accounts for more than half of their sales, with fisheries sonar being relegated to a strong second place. Other areas of work are oceanographic instrumentation and naval sonar, but neither of these is yet a large activity. My hosts on a recent visit were Mr. Ole Bernt Gammelseter, General Manager for Naval Systems, and Mr. Trond Helland.

The organization and operation of the company is interesting in several respects. In addition to the administrative and support services groups, there are five divisions, four of these being product/customer oriented for the sales areas mentioned earlier. About half of the employees are engineers, and many of these are in the research and development division, which is responsible for research, development, and equipment design for all products. About 25 percent of total sales volume is spent in this area. The small total number of employees (190) is misleading because it is the company's policy to design their equipment in-house but to subcontract for the fabrication of most subsystem components, such as electronic circuit boards, power supplies, power amplifiers, displays, cabinets, and mechanical assemblies. Final assembly and testing are done in-house. The sole exception to this plan is transducer fabrication, which is done entirely by Simrad. Much of the electronic and machining work is done by the small local companies.

The plant (10,000 m^2 of floor space) looks more like an R&D operation than a factory. The transducer section is adequate but has little specialized equipment. They have a good underwater sound tank (5×4×3.5 m, unlined), which is instrumented with a mechanical positioning system and a full set of modern electronic instrumentation for transducer calibration. They also have a small underwater acoustic test station at a pier on the fjord, which is only a few steps away. The company owns a 20-m power boat, which is used jointly for R&D and for demonstration of equipment to customers. This boat is equipped with several sonars and depth sounders but still has room for experimental work. The nature of the water at Horten is very good for sonar research because water depths of several hundred meters can be reached in 15 minutes. However, the fjord has some sharp thermoclines during several months, and this severely reduces the detection range for hull-mounted sonars. The water generally freezes over for a period in the winter.

The transducers I saw were well made and of conventional design in most respects. Some were arrays of flat elements, and others were of the tonpils

type (vibrating ceramic piston with head and tail masses) with the mounting being on the nodal plane of the ceramic. In one design the transformer is mounted on the tail mass. Simrad buys the ceramic cut to size and polarized. The company even continues to use magnetostrictive elements for some of the older systems. An epoxy-foam material is used for pressure-release mounting of elements where required. The aim of the company is to develop a limited number of parts such as standard electronic modules, transducers, and displays, and to use these in a variety of devices for specific applications. Thus one finds many of the acoustic and electronic parameters the same in rather different pieces of equipment.

The heart of the Simrad offshore equipment is an underwater system for measuring precisely the range and direction from an elementary sonar to a small transponder. The sonar employs a trainable transducer which operates in the super-short baseline mode. That is, the receive transducer is split (monopulse) so that the direction to the transponder can be determined precisely by measuring the difference in time of arrival. The system (HPR-309) can track 16 transponders at a time and display the information on a PPI display. In application, the sonar (an interrogator) is mounted on a platform (fixed or mobile), and transponder units (battery powered) are attached to the devices which are to be tracked, such as the legs of an offshore rig which is to be placed on a mounting base. Precision is required, and the operation must succeed the first time. The same basic system is used for oil well re-entry, pipeline laying, and tracking of remotely operated vehicles and deep-towed seismic arrays. In brief, it can be used to track precisely the location of anything to which a transponder can be attached. I was told that Simrad has about 80 percent of the Norwegian work of this type. The company also feels that the same basic system can be used for routine precise navigation along channels (and similar systems have been so used), but this application has not yet been exploited. A simpler device, known as the universal range sounder (URS) measures range only. It is used for precise alignment of a large ship for docking or for positioning in a dry dock. These small devices operate at 750 kHz and give a range accuracy of about 10 cm, but the range is only a few tens of meters at most. In general an array of URS's would be employed rather than a single unit.

Fisheries sonar is still a major product for Simrad, and they have a large part of the international market--a market which is not as good as it was a decade ago. Echo sounders (downward-looking, single-beam sonars) are universally used by fisherman both to measure the water depth and, more important, to detect schools of fish. Simrad markets a family of such instruments, which are fairly conventional in terms of acoustic parameters. These can be procured to operate at frequencies from 12 to 200 kHz, with 38 kHz being a popular choice. It is becoming more commonplace to use a dual-frequency unit. Beamwidths are usually quite wide, being on the order of 4 to 20 degrees, and pulse lengths range from 0.1 to 30 ms. One model, designed for hydrographic survey work can incorporate up to four frequencies, including a 710-kHz unit. Classifying fish species and estimating the density of fish schools is still more art than science, and most fishermen use the echo strength to help estimate the size of the schools. Simrad has developed a signal-processor adjunct to echo sounders, a digital echo integrating unit which gives a quantitative read-out of fish density. Another adjunct is a towed device which acoustically measures the position of the fish trawl footrope, of the headline, and of fish near the trawl. By nonacoustic means, the quantity of fish in the net cod is measured.

The company's main thrust in fish-finding sonar is with the more advanced type of multiple beam, electronically scanned type. One example is a 34-kHz system which forms 17 beams to cover an 85-degree sector, which can be mechanically trained through 360 degrees and tilted from +15 to -105 degrees. The ability to tilt is important in the tracking of fish schools. The beamwidth is fairly coarse, being 9 degrees in azimuth and 7 degrees in elevation. The pulse length is variable up to 110 m. Ranges up to 2000 m are available. The transducer array is planar, with phase-shift beamformers. The array can be stabilized in roll and pitch. The transducer array is protected by a fiberglass or rubber streamlined dome, which can be pressurized to allow higher source levels (up to 232 dB).

A standard Simrad display is a 14-inch color CRT, 512-line resolution, refreshed at 50 Hz. This digital system uses three colors to represent echo intensity and three colors for alphanumeric and tracking data. The central beam of the array is also used to provide an aural output, which seems to be used consistently by fishermen to learn something about the nature of the echoes from the fish schools.

If one wants to have a full 360 degrees of azimuthal coverage (instead of the 85 degrees of the set just described), the easiest solution is to use a circular or cylindrical array and form the appropriate number of beams, which are then scanned electronically within the duration of the pulse. Simrad has developed some examples of this type of sonar. The disadvantage of this configuration is that it is difficult to design the array so that the beams can be steering in the vertical plane (that is, be tilted down). To overcome this problem, the company has developed a new series in which the transducer array is in the form of a section of a sphere. For horizontal search, a ring of elements in a horizontal plane is used to form the beams to give 360-degree coverage. In another mode a semicircular array of elements in the vertical plane is used to form multiple downward-looking beams. These form a swath type of depth sounder, and the beam outputs are displayed on the lower half of the color display. At the same time, another semicircular array of elements can cover the forward 180 degrees. Other elements cover a hemispherical surface. These can be selected to form semicircular arrays in any plane from horizontal to vertical (downward). These beam outputs are portrayed on the top half of the display. The transducer for this type of sonar is more complex than either a simple planar or cylindrical array, but it has the nice feature of providing electronic scanning in three dimensions. This technique is incorporated into three current Simrad sonars. Two of these operate at 57 kHz, and the array can be lowered and retrieved through a 20-cm pipe. The beamwidth (horizontal and vertical) is 13 degrees, which only requires an aperture of 13 cm.

Recently Simrad has started to penetrate the naval sonar field, and with some success. The company markets several sonars similar to those just described, for antisubmarine warfare and surveillance applications, primarily for use on small boats (down to 150-ton vessels). Simrad was successful in its bid to furnish the scanning sonars for use on the new Norwegian Coast Guard boats. This sonar, the SS105, operates at 14 kHz and uses a cylindrical array to form 48 beams, each 11 degrees in azimuth and 12 degrees in elevation, to cover 360 degrees. Pulse lengths of 10, 30, and 60 ms are provided, with range scales from 2 to 16 km. The display is a 240-mm PPI. Each beam employs split-beam processing. The parameters of this sonar are similar to those of US Navy sonars of the fifties, but the engineering and fabrication are likely to be modern.

Simrad's success in the oceanographic instrumentation market has been modest. Concentration is on equipment to support fish surveys and hydrography. For fisheries research the company works closely with the Institute for Marine Research (IMR) in Bergen and for hydrography with the Continental Shelf Institute (IKU) in Trondheim. In the latter area, one of the major recent developments has been a multibeam echo sounder (the EM100) for bottom mapping (bathymetric) surveys. The equipment is similar in principle to two US developments: the General Instruments Sea Beam and Hydrochart and the Sperry BOTOSS. The Simrad system operates at 95 kHz and forms 32 beams (each 3 degrees) to cover 80 degrees. Because of electronic roll stabilization, the normal sector is reduced to 26 beams and 65 degrees. Pitch stabilization is within 0.2 degrees. The array is composed of 96 elements on a 45-cm radius to cover a 120-degree sector. The same array is used for both transmission and reception. The received signals are digitized (8 bit) and quadrature sampled for phase shift beam formation. The pulse length is either 0.2 or 0.6 ms. The designed maximum slant range is 550 m. The trunk for the transducer array is 1.0-m wide. The data are displayed on a 14-inch color CRT and recorded on magnetic tape. A graphic recorder is included also. I was favorably impressed with the amount of company-conducted research and data collection which was done in support of this development.

Up to now Simrad has not done much work toward developing side-scan sonar, but this situation is likely to change. Researchers have been working with IKU on a side-scan interferometric sonar for bottom-contour mapping. This sonar was developed by IKU (see below), and Simrad will build a production prototype for IKU. I believe that they have plans to market the system commercially. Simrad also plans to become more involved with sub-bottom profilers and has built one nonlinear parametric array for this application.

Most of the Simrad sonars (as with most fisheries sonar) do not have very high resolution and therefore would not be very useful for applications such a mine hunting. Simrad researchers have done some studies of high-frequency, high-resolution devices, but they are noncommital about technical details and future plans. The coastal environment of Norway might be a good place to use such equipment.

Simrad also markets a relatively simple Doppler speed log. This device operates at 1.0 MHz and measures speed only along ship heading. It uses two transducers, each tilted down 30 degrees from the vertical, pointing fore and aft. The bottom lock mode is useful only for water depths of about 20 m, too shallow for most Norwegian waters. Normal operation is to measure the Doppler shift relative to the water volume in the range from 4.5 to 6.0 m below the keel. The transducer beamwidths are 3.5 degrees. The accuracy is stated to be 2 percent of speed.

Continental Shelf Institute (IKU), Trondheim

IKU is a Norwegian not-for-profit research institute established in 1969 to conduct research in the continental shelf area of Norway, the Arctic Ocean, and along the coast. Its charter is to:

- Map and explore the geology, topography, and environment of the shelf.
- Develop methods and equipment for doing the above and to maintain and operate the equipment.
- Conduct surveys.
- Do research on the shelf's resources.
- Train people for research in the shelf environment.

This program is to be conducted under contracts and grants from corporations, the government, and other research institutes. Basically, it is the responsibility of the institute to obtain the bulk of its own funding, with only a small amount coming from the government as foundation support.

The staff totals 170, with 29 in organic geochemistry, 40 in geology, 23 in oceanography, 30 in technology, and the rest in administration and services. Total income in 1983 was NKr 80 million, of which NKr 73 million was from external contracts ($1.00 = NKr 7.8 at current exchange rates). Eighty-two percent of this funding was from oil companies. Projects include pipeline surveys; tower foundation surveys; oil spill behavior, control, and dispersal; arctic climate; and oceanographic surveys (e.g., winds, waves, currents).

Recently I visited the Technology Department to learn some of the details of a side-scan topographic survey sonar that has been developed at IKU. My host was Dr. John Klepsvik, Senior Scientist, whose dissertation for his degree from Norwegian Technical Institute (University of Trondheim) was based on the development of the sonar (Klepsvik, 1983). IKU has a strong interest in bottom-mapping sonars, and the staff has worked with several commercial units. Conventional side-scan sonars do not provide a quantitative measure of bottom relief and bathymetry, and such data are often required in offshore projects. The data can be obtained with single-beam depth sounders, but the process is slow if high-density maps are required. The multibeam-swath depth sounder is a better solution, and IKU has worked with Simrad in the development of such a device (see preceding section).

Several groups have worked on developing a towed side-scan sonar to provide the desired information. These include the Institute of Oceanographic Sciences, Birmingham University, and Bath University (all in the UK). (*ESN* 37-9:378-379 [1983] provides a summary of this work and a detailed description of the Bath project.) IKU decided to build such a system, and from 1979 to 1983 Klepsvik worked on the project. He told me that he was familiar with the work done at the three institutions mentioned above; his dissertation references the first two but not the highly relevant work by Cloet at Bath University, which leads me to believe that he may not have known about it. All of these projects involve the use of two or more horizontal-line transducer arrays, stacked in the vertical plane to form an interferometer, to make a precise measurement of the range and angle to a scattering patch on the ocean floor. With this information the height of the patch, relative to the arrays, can be calculated. There are a number of major problems to be solved in the implementation of a practical instrument.

The design, construction, and evaluation of the side-scan topographic survey sonar system at IKU was a major project, and Klepsvik and his associates seem to have done very thorough work. Klepsvik's dissertation includes--in addition to a detailed description of the design, construction, and sea testing of the system--a good review of prior bottom-backscattering work (theoretical and experimental) and a good development of the theory for the IKU instrument.

The sonar operates at a frequency of 164 kHz, with a bandwidth of 11 kHz. One line array is 38.3 λ long and the other is 57.5 λ long. The long array is used for transmission and reception and the short one for reception only. By using lines of different lengths, the minor lobes of the composite beam patterns are strongly suppressed. The composite patterns have a beamwidth of 0.9 degrees in the horizontal plane and 25 degrees in the vertical plane. The separation in the vertical plane of the phase centers of the two receive arrays

is 1.9 λ, which gives only limited ambiguity of the interference fringes. Phase of the interference lobes is measured directly and used to calculate the angle to the scattering patch.

With a high signal (reverberation)-to-noise ratio, the precision of angular direction is determined to within 0.1 degree, within the unambiguous sector of 30 degrees. The pulse length of 40 cycles gives a range resolution of about 18 cm. Knowing the range and angle, one can readily compute the depth of the scattering patch relative to the position of the transducer arrays, which is the same as the towed body. It is obvious that the towed body should be stable and that its motion (roll, pitch, and yaw) must be measured precisely and used to correct the sonar data. Also, the depth of the towed body must be measured accurately in order to calculate the bottom topographic relief. The IKU system seems to do all of this very well. Data can be collected for ranges up to 300 m, but the quality of the data decreases with increasing range.

A limited number of tests have been made at sea with the experimental system, and the results seem to be believable. The sonar surveys have been made using a precision microwave navigation system, but there are no high-density surveys of the same areas made by other means to use for comparison. However, spot checks of the side-scan data with other measurements are in reasonable agreement.

In addition to providing data for topographic contour plots, the system provides data which can be used to calculate bottom-backscattering coefficients. The values obtained by Klepsvik, as a function of grazing angle in the range from 10 to 45 degrees, are in general agreement with published data for similar bottom types. I consider this aspect of the IKU program to be very valuable and useful.

The IKU instrument is really only half of a system because only one sonar to look to one side was built. The current plans are for Simrad A/S to build a full two-sonar prototype system which will be tested extensively and used in IKU surveys.

Institute of Marine Research, Bergen

IMR has a major research effort in support of the fisheries business and has been using sonar for fish surveys research for at least 15 years. Staff members such as O. Nakken, K. Olsen, and I. Rottingen have published the results of their work in a number of IMR reports and in the archival literature. Their work is similar in nature and purpose to that done at several places in the UK, in Denmark (*ESN* 38-2:82-85 and 38-6:325-327 [1984]), and perhaps elsewhere. The common goal is to use echo-ranging depth sounders and sonars to detect schools of fish, identify species, and estimate the number or volume of fish in a school. The goal is proving to be an elusive one in spite of considerable effort by a number of workers over an extended period. However, steady progress is being made, and the research results have significance beyond just the area of fisheries technology.

On a recent visit to the University of Bergen, I was briefed by Dr. Kenneth Foote on some of his current work on using sonar to study fish. Foote is an American who works primarily for IMR but also has a joint appointment in the Applied Mathematics Department at Bergen University. After graduating from Brown University he came to Bergen several years ago on a postdoctoral fellowship to study under Sigve Tjotta and Jacqueline Naze-Tjotta, both professors of applied mathematics. He liked the environment, became interested in the fisheries problem, and has stayed on, though he recently spent a sabbatical year at Brown. Foote has published a large number of papers on his work with the fish-counting problem. Most of his early papers (1978-82) involved in-depth statistical analyses of older data collected by others at IMR, but since 1980 he has been making new measurements in a semi-laboratory-controlled environment. The general experimental arrangement is to use a vertically directed, single-beam echo sounder to obtain echoes from fish restrained in a net cage. This arrangement is used because it corresponds to the configuration of a down-looking echo sounder on a fishing boat. In almost all cases the resolution cell (determined by the beamwidth and pulse length) is much larger than a single fish. Foote's equipment includes four Simrad echo sounders operating simultaneously at 38, 50, 70, and 120 kHz with beamwidths on the order of 20 degrees and range resolution on the order of 50 cm. For targets he uses a variety of fish (mostly with swim bladders) of interest to the Norwegian fisherman. Foot uses both the echo sounders and underwater TV to make measurements on various numbers of fish. In parallel, he makes measurements on a single anesthetized fish, which can be held stationary and variously oriented. The target strength of a fish is a function of species, length and size, orientation, and frequency. To interpret fish echo data it is necessary to make some assumptions in regard to the species

being detected and the distribution of sizes. Foote has drawn the following conclusions from his research:

1. The number of fish and the echo energy are linearly related. Multiple scattering is not important.
2. The target strengths of anesthetized fish and swimming fish are essentially the same, and therefore the data obtained on the former can be applied to the latter.
3. Echo integration is a valid means for estimating the number of fish in a school.
4. For fish with swim bladders, more than 90 percent of the echo energy is due to scattering from the bladder.

It is critically important to have a good standard target against which fish echoes can be calibrated by comparison. Foote has spent considerable effort on measuring the target strengths of small metal spheres, which are used as standard targets, and has published several papers on his work. He has concluded that a 60-mm solid copper sphere is a suitable type and that its target strength can be measured with an accuracy of 0.1 dB. Variation with time and between samples is not significant.

Some of Foote's more recent work involves means for detecting fish avoidance of trawl nets and wires, energy versus peak amplitudes for fish echoes, and the use of split-beam echo sounders. The IMR program seems to be a good one and is directed toward developing techniques which will be directly applicable to the commercial fishing business. The staff is looking at a number of relevant problems in a thorough and systematic manner, and progress, although slow, appears to be steady and significant.

Reference

Klepsvik, John Addvar, "Statistical Characteristics of the Sea-Bed Reverberation Process With Applications to Wide-Swathe Bathymetric Mapping," Continental Shelf Institute, Trondheim, Norway, Publication No. 111 (December 1983), 118 pp.

6/21/84

NEWS & NOTES

EDUCATION AND HUMAN DEVELOPMENT IN THE UK

Government-supported research on education and human development in the UK is funded through a committee of the Economic and Social Research Council (ESRC). The ESRC *Newsletter 52* for June 1984, titled *Learning to be Adult*, is devoted primarily to examples of recent research activities in this area. Articles include: Learning about Number; Parents, Teachers and the Infant School; Mental Testing and Education in England and Wales; Learning Your Place; From Child to Adolescent: Transfer from Primary to Secondary School; Teachers, Trainers, and Computer-Based Education; Population History, Microcomputers and Education; What Do We Mean By "Standards" in Education?; and Knowing Your Place--Finding Your Place.

The ESRC Committee on Education and Human Development is chaired by Philip Levy, Professor of Psychology at the University of Lancaster. In *Newsletter 52*, Levy reviews the topics presently given priority for funding: social influences on child development (e.g., the relation between home and school, the development of social cognitions); teacher education (e.g., the response to changing needs, the importance of understanding the epistomological bases of subjects in the school curriculum); special needs (e.g., individual differences among the less able, delayed development of relationships); regional varieties of British English; information technology and knowledge structures, especially aimed at the development and application of intelligent knowledge-based computer systems in education; societal changes affecting teenagers (e.g., increased unemployment, shifting expectations about preparation provided by school); and studies of children in professional care. A committee paper detailing these areas of activity, entitled *Priorities for Research*, is available from The Secretary, Education and Human Development Committee, ESRC, 1 Temple Avenue, London EC4Y 0BD, UK.

Richard E. Snow
6/21/84

NEW NORTH SEA ENVIRONMENTAL ATLAS

Anyone interested in the geology, oceanography, and meteorology of the North Sea should take a careful look at a new atlas published by Oilfield Publications Limited (P.O. Box 11, Ledbury, Herefordshire HR8 1BU, England). The *North Sea Environmental Guide* consists of 40 maps of environmental data, mostly environmental extremes. The contents include: environmental data acquisition,

wind distribution, bathymetry, mean surface temperature, mean surface air temperature, mean sea level pressure, visibility, cloud cover, precipitation, frequency of fog, 50-year maximum wind speeds, 50-year maximum wave heights, tidal rise, extreme surface current, wave heights of 2 m or less, North Sea casualties, oil and gas fixed installations, and oil and gas fields.

This statement is from the introduction: "The maps of environmental extremes have been painstakingly developed by widely-approved statistical methods and meteorological and oceanographic expertise using all available data comprising hundreds of thousands of wind and wave observations drawn from ships' log books over periods of many years and the large amounts of measured data which has become available in more recent years. This set of maps is more comprehensive, more detailed and more coherent than any previously published maps of the North Sea environmental parameters. Nevertheless it has to be emphasised that the depicted isopleths are only intended as reasonably good guidance and do not dispense with the necessity for full site-specific studies to establish proper design criteria."

The price is £35 ($49) plus £2.50 for postage.

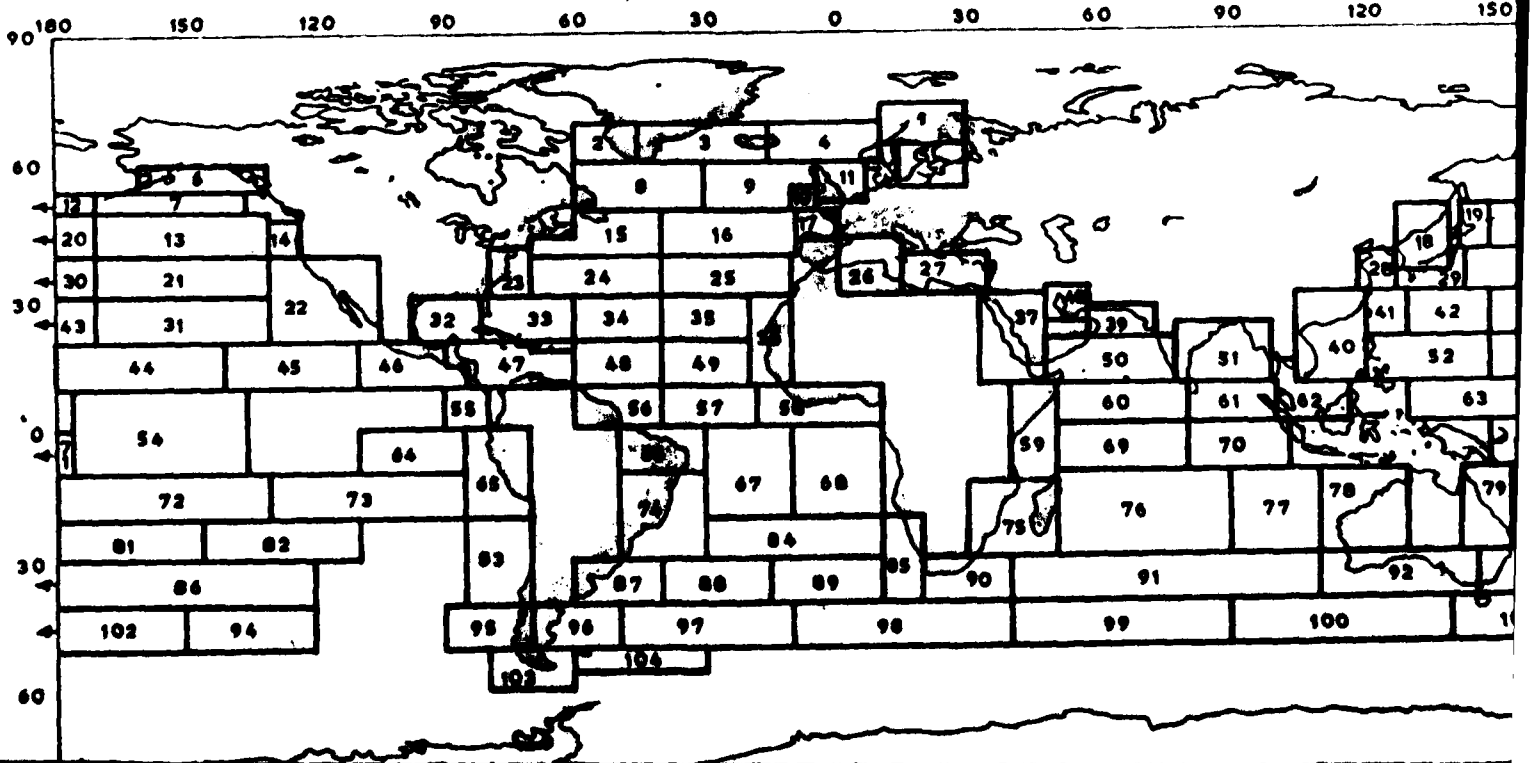
Robert Dolan
7/2/84

NMI DEVELOPS NEW GLOBAL WAVE-DATA ATLAS

A new atlas of global wave statistics is being compiled by the UK's National Marine Institute (NMI). The atlas is being produced in collaboration with the UK Meteorological Office, which is supplying the source data and providing advice on the global coverage and climatology.

In 1967 a compilation of visual wave data was published under the title *Ocean Wave Statistics* and is still widely used. However, since 1967 the demand for reliable wave data has greatly increased, mostly associated with the rapid expansion of ocean engineering activity, and advances have been made in methods of analysis.

In recent years considerable effort has been devoted to collecting wave data from instrumental sources and to developing hindcasting (models) from visual observations. The UK Meteorological Office has installed a global archive of visual observations that, when complete, will contain all the visual data reported since 1949 and for all areas of the world except those where the data were reported by the USSR. Research into the reliability of visual data has shown that where there are large samples, the visual wave-height statistics are in good agreement with those derived from actual measurements. This research has also demonstrated that some wave-height observations are clearly incorrect and



therefore result in predictions of extreme values which are unreliable. In the case of the wave period, the visual observations have been shown to be seriously misleading and therefore cannot be used to predict the responses of ships or offshore structures.

The NMI has developed a computer program to use the visual data in order to derive reliable statistics for long-term wave height and wave period. This program uses methods based on parametric modeling of the correlations between wave height, wind speed, and wave

AREA 138
ALL SEASONS

DIRECTIONAL SECTOR 0° - 45°

NUMBER OF OBSERVATIONS = 3254

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS)											
	<4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	TOTAL
0.0- 0.5	0.2	3.1	9.8	7.3	2.6	0.6	0.1	-	-	-	-	23
0.5- 1.0	0.1	3.7	23	37	24	8.5	2.0	0.3	-	-	-	99
1.0- 1.5	-	1.5	17	44	44	22	7.2	1.7	0.3	-	-	138
1.5- 2.0	-	0.7	10	30	36	33	13	3.8	0.8	0.2	-	140
2.0- 2.5	-	0.3	5.0	27	44	38	17	5.7	1.5	0.3	0.1	138
2.5- 3.0	-	0.1	3.2	18	36	32	18	6.7	1.8	0.5	0.1	118
3.0- 3.5	-	0.1	1.7	11	25	26	16	6.9	2.2	0.6	0.1	90
3.5- 4.0	-	-	0.8	6.8	17	20	14	6.4	2.2	0.6	0.1	68
4.0- 4.5	-	-	0.5	4.1	12	15	11	5.6	2.1	0.6	0.2	51
4.5- 5.0	-	-	0.3	2.5	7.7	11	8.8	4.7	1.8	0.6	0.2	37
5.0- 5.5	-	-	0.1	1.5	5.1	7.7	6.7	3.8	1.6	0.5	0.1	27
5.5- 6.0	-	-	0.1	0.9	3.3	5.4	5.0	3.0	1.3	0.5	0.1	20
6.0- 6.5	-	-	-	0.6	2.2	3.8	3.7	2.4	1.1	0.4	0.1	14
6.5- 7.0	-	-	-	0.3	1.4	2.6	2.7	1.8	0.9	0.3	0.1	10
7.0- 7.5	-	-	-	0.2	0.9	1.8	1.8	1.4	0.7	0.3	0.1	7.3
7.5- 8.0	-	-	-	0.1	0.6	1.2	1.4	1.0	0.5	0.2	0.1	5.2
8.0- 8.5	-	-	-	0.1	0.4	0.8	1.0	0.7	0.4	0.2	0.1	3.7
8.5- 9.0	-	-	-	-	0.2	0.6	0.7	0.5	0.3	0.1	-	2.6
9.0- 9.5	-	-	-	-	0.2	0.4	0.5	0.4	0.2	0.1	-	1.8
9.5-10.0	-	-	-	-	0.1	0.2	0.3	0.3	0.2	0.1	-	1.2
10.0-10.5	-	-	-	-	0.1	0.1	0.2	0.2	0.1	0.1	-	0.8
10.5-11.0	-	-	-	-	-	0.1	0.1	0.1	0.1	-	-	0.5
11.0-11.5	-	-	-	-	-	-	0.1	0.1	-	-	-	0.3
TOTAL	0.3	8.9	72	190	275	220	132	58	20	6.1	1.6	1000

DIRECTIONAL SECTOR 45° - 90°

NUMBER OF OBSERVATIONS = 3175

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS)											
	<4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	TOTAL
0.0- 0.5	0.3	6.1	18	16	6.4	1.8	0.2	-	-	-	-	48
0.5- 1.0	0.1	3.7	28	42	28	11	2.6	0.5	0.1	-	-	112
1.0- 1.5	-	1.4	16	42	42	22	7.1	1.7	0.3	-	-	132
1.5- 2.0	-	0.6	10	35	45	28	12	3.3	0.7	0.1	-	136
2.0- 2.5	-	0.3	5.0	26	40	31	14	4.6	1.1	0.2	-	123
2.5- 3.0	-	0.1	3.5	18	32	28	15	5.3	1.3	0.3	0.1	103
3.0- 3.5	-	0.1	2.0	12	24	24	14	5.4	1.6	0.4	0.1	83
3.5- 4.0	-	-	1.2	7.7	18	19	12	5.1	1.7	0.4	0.1	65
4.0- 4.5	-	-	0.7	5.0	13	15	10	4.6	1.6	0.4	0.1	50
4.5- 5.0	-	-	0.4	3.3	8.8	11	8.2	4.0	1.5	0.4	0.1	39
5.0- 5.5	-	-	0.2	2.2	6.3	8.9	6.6	3.4	1.3	0.4	0.1	29
5.5- 6.0	-	-	0.1	1.4	4.4	6.4	5.2	2.8	1.1	0.4	0.1	22
6.0- 6.5	-	-	0.1	0.9	3.1	4.7	4.1	2.3	1.0	0.3	0.1	17
6.5- 7.0	-	-	0.1	0.6	2.2	3.5	3.1	1.8	0.8	0.3	0.1	13
7.0- 7.5	-	-	-	0.4	1.5	2.6	2.4	1.5	0.7	0.2	0.1	9.4
7.5- 8.0	-	-	-	0.3	1.1	1.9	1.8	1.2	0.5	0.2	0.1	7.1
8.0- 8.5	-	-	-	0.2	0.7	1.4	1.4	0.9	0.4	0.2	0.1	5.3
8.5- 9.0	-	-	-	0.1	0.5	1.0	1.0	0.7	0.4	0.1	-	3.8
9.0- 9.5	-	-	-	0.1	0.4	0.7	0.8	0.5	0.3	0.1	-	2.8
9.5-10.0	-	-	-	0.1	0.2	0.5	0.6	0.4	0.2	0.1	-	2.1
10.0-10.5	-	-	-	-	0.2	0.3	0.4	0.3	0.2	0.1	-	1.5
10.5-11.0	-	-	-	-	0.1	0.2	0.3	0.2	0.1	0.1	-	1.1
11.0-11.5	-	-	-	-	0.1	0.2	0.2	0.1	0.1	-	-	0.7
11.5-12.0	-	-	-	-	-	0.1	0.1	0.1	0.1	-	-	0.5
12.0-12.5	-	-	-	-	-	0.1	0.1	0.1	-	-	-	0.3
TOTAL	0.4	13	83	212	378	222	122	51	17	4.8	1.3	1000

DIRECTIONAL SECTOR 90° - 135°

NUMBER OF OBSERVATIONS = 3184

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS)											
	<4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	TOTAL
0.0- 0.5	0.4	6.8	17	13	4.8	1.1	0.2	-	-	-	-	43
0.5- 1.0	0.1	8.3	28	43	28	10	2.4	0.6	0.1	-	-	119
1.0- 1.5	-	3.2	26	47	44	22	7.3	1.8	0.3	0.1	-	160
1.5- 2.0	-	1.0	13	40	40	31	12	3.5	0.8	0.2	-	140
2.0- 2.5	-	0.5	7.4	28	42	32	15	4.8	1.3	0.2	0.1	132
2.5- 3.0	-	0.2	4.2	18	33	28	15	5.6	1.6	0.4	0.1	108
3.0- 3.5	-	0.1	2.3	12	24	23	14	5.8	1.7	0.5	0.1	83
3.5- 4.0	-	-	1.3	7.8	17	18	11	5.0	1.7	0.5	0.1	63
4.0- 4.5	-	-	0.7	4.8	12	13	9.2	4.4	1.6	0.5	0.1	46
4.5- 5.0	-	-	0.4	3.0	7.8	9.0	7.2	3.6	1.4	0.4	0.1	34
5.0- 5.5	-	-	0.2	1.8	5.3	7.0	5.8	3.0	1.2	0.4	0.1	25
5.5- 6.0	-	-	0.1	1.2	3.5	5.0	4.2	2.3	1.0	0.3	0.1	18
6.0- 6.5	-	-	0.1	0.7	2.4	3.5	3.1	1.9	0.8	0.3	0.1	13
6.5- 7.0	-	-	-	0.5	1.6	2.5	2.3	1.4	0.6	0.2	0.1	9.2
7.0- 7.5	-	-	-	0.3	1.0	1.7	1.7	1.1	0.5	0.2	0.1	6.6
7.5- 8.0	-	-	-	0.2	0.7	1.2	1.2	0.8	0.4	0.2	-	4.6
8.0- 8.5	-	-	-	0.1	0.4	0.8	0.9	0.6	0.3	0.1	-	3.2
8.5- 9.0	-	-	-	0.1	0.3	0.5	0.6	0.4	0.2	0.1	-	2.2
9.0- 9.5	-	-	-	-	0.2	0.3	0.4	0.3	0.2	0.1	-	1.5
9.5-10.0	-	-	-	-	0.1	0.2	0.3	0.2	0.1	-	-	1.0
10.0-10.5	-	-	-	-	0.1	0.1	0.2	0.1	0.1	-	-	0.6
10.5-11.0	-	-	-	-	-	0.1	0.1	0.1	-	-	-	0.3
TOTAL	0.6	19	80	204	376	311	193	67	19	4.7	1.0	1000

DIRECTIONAL SECTOR 135° - 180°

NUMBER OF OBSERVATIONS = 3226

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS)											
	<4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	TOTAL
0.0- 0.5	1.6	18	30	20	7.8	1.6	0.3	-	-	-	-	73
0.5- 1.0	0.4	16	41	32	31	11	2.8	0.6	0.1	-	-	140
1.0- 1.5	0.1	6.9	31	37	47	22	7.3	1.9	0.4	0.1	-	171
1.5- 2.0	-	2.4	18	46	48	30	11	3.2	0.8	0.2	-	150
2.0- 2.5	-	1.1	11	32	38	26	12	3.8	1.1	0.3	0.1	136
2.5- 3.0	-	0.5	6.4	21	29	22	11	4.0	1.2	0.3	0.1	95
3.0- 3.5	-	0.3	3.6	13	21	17	9.3	3.7	1.2	0.3	0.1	70
3.5- 4.0	-	0.1	2.0	8.3	14	13	7.5	3.2	1.1	0.3	0.1	50
4.0- 4.5	-	0.1	1.1	5.2	9.0	8.3	5.0	2.6	0.8	0.3	0.1	33
4.5- 5.0	-	-	0.6	3.2	6.3	6.0	4.4	2.1	0.8	0.3	0.1	25
5.0- 5.5	-	-	0.4	2.0	4.2	4.7	3.2	1.6	0.6	0.2	0.1	17
5.5- 6.0	-	-	0.2	1.2	2.8	3.2	2.4	1.2	0.5	0.2	0.1	12
6.0- 6.5	-	-	0.1	0.8	1.8	2.2	1.7	0.9	0.4	0.1	-	8.2
6.5- 7.0	-	-	0.1	0.5	1.2	1.5	1.2	0.7	0.3	0.1	-	5.6
7.0- 7.5	-	-	-	0.3	0.8	1.0	0.8	0.5	0.2	0.1	-	3.8
7.5- 8.0	-	-	-	0.2	0.5	0.7	0.6	0.3	0.2	0.1	-	2.5
8.0- 8.5	-	-	-	0.1	0.3	0.4	0.4	0.2	0.1	-	-	1.6
8.5- 9.0	-	-	-	0.1	0.2	0.3	0.3	0.2	0.1	-	-	1.2
9.0- 9.5	-	-	-	-	0.1	0.2	0.2	0.1	0.1	-	-	0.8
9.5-10.0	-	-	-	-	-	0.1	0.1	-	-	-	-	0.2
TOTAL	2.0	35	146	265	263	171	80	31	10	2.9	0.7	1000

••• ALL TABLE ENTRIES ARE PROBABILITIES EXPRESSED IN PARTS PER THOUSAND •••

Figure 2. Data format for directional data.

period. The model has produced wave-height and wave-period statistics that are in good agreement with measured data.

The NMI atlas of wave data will concentrate on approximately 100 areas globally (Figure 1, page 514). These areas have been chosen with regard to climatic homogeneity, data availability, and potential interest to users.

The wave data will be presented in the form of "wave scatter diagrams"--i.e., joint probability distribution of wave data. Marginal probability distributions of both height and period will also be given. The data will be presented as probabilities in parts per thousand, with the wave-height classes in 0.5-m intervals and wave-period classes in 1-second intervals.

For each of the 100 areas the data will be presented in three categories: (1) all year for all directions; (2) all directions for four standard seasons--December through February, March through May, June through August, and September through November; (3) all seasons for eight directional sectors, each sector encompassing 45 degrees.

Figure 2 (less than half the size intended for the atlas) is a sample page for category 1.

The atlas will also contain explanatory notes regarding interpretation and an explanation of any special climatic considerations for areas that require either special seasons or directional data.

For further information, contact: Ms. N.M.C. Dacunha or Mr. N. Hogben, National Maritime Institute (Atlas Project), Faggs Road, Feltham, Middlesex, UK TW14 OLQ.

Robert Dolan
6/14/84

PROCEEDINGS OF SOLAR OSCILLATIONS CONFERENCE PUBLISHED

The proceedings of the conference "Oscillations as a Probe of the Sun's Interior," held in Catania, Italy, from 20 through 24 June 1983 have been published under the auspices of the Italian Astronomical Society. The proceedings are in two volumes, edited by Drs. G. Belvedere and L. Paternò of the University of Catania, and will appear in the journal *Memorie della Societa Astronomica Italiana*, Vol 55, Nos. 1 and 2 (1984). The proceedings contain both invited and contributed papers.

There has been significant progress in research on solar oscillations, a field now known as helioseismology. Although the field is still in its infancy, the study of solar oscillations has proven to be an important diagnostic tool. Such studies give information on topics such as the missing solar neutrinos, the primordial solar helium abundance, solar oblateness that has general relativistic significance, the ubiquitous 160-minute period of oscillation, and the variation of the solar angular velocity with radial distance from the center of the sun.

Solar oscillations are deduced primarily from the analysis of Doppler-shifted spectral lines into normal modes. In the theoretical description, the oscillations are of two types: pressure (or p-) modes that depend on the sound speed, and gravity (or g-) modes that depend on buoyancy and the density gradient. The first reported observations of g-modes were announced by Dr. George Isaak (University of Birmingham, UK) at the Catania meeting. Papers on observations, theory, models, and experimental methods are included in the proceedings.

Inquiries about the proceedings may be directed to:

Segreteria
Italian Astronomical Society
Largo Fermi 5
50125 Firenze
ITALY

R.L Carovillano
6/1/84

NEW POLICIES FOR ITALIAN ASTRONOMY JOURNAL

The Italian Astronomical Society (IAS) has appointed Dr. Roberto Pallavicini (Arcetri Astrophysical Observatory, Florence) as the managing editor of its journal, *Memorie della Societa Astronomica Italiana*. Pallavicini will be assisted by an editorial board consisting of officers of the IAS and headed by Dr. Livio Gratton (former director of the Frascati astrophysics laboratory). The new principal purpose of the journal will be to promote information flow on the astronomical sciences outside Italy. Thus, instructions on journal publication requirements and all published papers will be in English for the first time. The journal will emphasize the publication of conference proceedings and thematic volumes on special topics. Original research papers will

be referred to other journals in the field. The first special-topics volume is expected to be published in September. The volume will consist of a collection of invited papers, selected for overview and topical coverage, relating to the Solar Maximum Mission.

Publication expenses will be partially underwritten by the IAS, and purchase prices for nonmembers of the IAS will be modest. Inquiries to arrange for the publication of conference proceedings or purchases may be directed to:

Dr. Roberto Pallavicini
Italian Astronomical Society
Osservatorio di Arcetri
Largo Fermi 5
50125 Florence,
ITALY

R.L. Carovillano
6/1/84

ZWO ANNOUNCES POSTDOCTORAL AWARDS

The Netherlands Organization for the Advancement of Pure Research (ZWO) has announced its 1984 awards under the "Constantijn en Christiaan Huygens-programma." These postdoctoral grants are intended to provide support for promising young researchers.

There were five awards in physics, four in biology, three in biochemistry, two in medicine, one in chemistry, four in linguistics and literature, two in technology, and one each in law, sociology, social geography, psychology, physical geography, and theology.

For more information about the ZWO's programs, see *ESN* 38-8:440-442 (1984).

Larry E. Shaffer
6/26/84

ONRL STAFF CHANGE

This month we welcome Dr. David L. Venezky; his specialty is chemistry. Dr. Venezky is on leave from the Naval Research Laboratory, Washington, DC, where he is Head of the Inorganic and Electrochemistry Branch, Chemistry Division.

ONRL COSPONSORED CONFERENCES

ONR, London, can nominate two registration-free participants in the conferences it supports. Readers who are interested in attending a conference should write to the Scientific Director, ONRL, Box 39, FPO New York 09510.

Third International Conference on Water and Ions in Biological Systems, Bucharest, Roumania, 2-6 October 1984.

Ninth European Specialist Workshop on Active Microwave Semiconductor Devices, Veldhoven, Netherlands, 10-12 October 1984.

EUROPEAN VISITOR TO THE US SPONSORED BY ONR, LONDON

Visitor	Area of Interest	Organizations to be Visited	Want Information? Contact at ONRL
Mr. David M. Lane Dept. of Electrical and Electronic Engineering Heriot-Watt University 31-35 Grassmarket Edinburgh, Scotland	Autonomous Submersible System	Naval Research Laboratory Washington, DC Naval Ocean Systems Center, San Diego, CA (October 84)	James W. Daniel

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SCIENCE NEWSBRIEF FOR JULY

The following issue of *Science Newsbrief* was published by the ONR, London, Scientific Liaison Division during July. *Science Newsbrief* provides concise accounts of scientific developments or science policy in Europe and the Middle East. Please request copies, by number, from ONR, London.

Science Newsbrief Number	Title
2-4-84	Europe's Largest Cell Bank Slated for UK, by Thomas C. Rozzell.

JUNE/JULY MAS BULLETINS

The following *Military Applications Summary (MAS) Bulletins* were published by the ONR, London, Military Applications Division during June and July. The *MAS Bulletin* is an account of naval developments in European research, development, test, and evaluation. Its distribution is limited to offices with the US Department of Defense. DoD organizations should request copies of the *Bulletins*, by number, from ONR, London.

MASB Number	Title
34-84	Mine Warfare Highlights at Mostra Navale Italiana
35-84	Fiber-Optic Gyroscope
36-84	FATIGUE 84--The Second International Conference on Fatigue and Fatigue Thresholds
37-84	The Tenth European Rotorcraft Forum
38-84	New NATO Oceanographic Research Vessel
39-84	Oceanographic Acoustic Processing Techniques at the University of Bath
40-84	Fiber Optics Technology/Applications--Marconi Research Laboratories (UK)
41-84	New Long Life Diode Lasers for Fiber Optic Transmission Systems--New Products from Standard Telephones and Cables (STC)
42-84	The Zero-Factor Transform (ZFT)--A New High-Speed Technique for Signal Processing
43-84	European Aerospace Updates
44-84	Second Quarterly Index 1984
45-84	Arctic Structures

ONRL REPORTS

To request reports, check the boxes on the self-addressed mailer and return it to ONR, London.

R-7-84: *Physics in Europe--A Data File of Selected Research*, by David Mosher. This report describes a data file of 1200 entries on European research in physics and related areas. The tables provided allow one to access research projects by subject matter and location.

R-8-84: *Bioelectromagnetics Research in France--An Assessment*, by Thomas C. Rozzell. Over the past decade, France played a major research role in bioelectromagnetics (BEM)--studies of the interaction of electromagnetic fields with biological systems. While the total French program was moderate compared with those of other countries, the contributions it made were highly significant and had an impact on almost every area of the field. This report examines recently completed BEM research and discusses some work done over the past 3 to 5 years.

R-9-84: *Bioelectromagnetics Research in West Germany: An Assessment*, by Thomas C. Rozzell. This report highlights some of the key research that has been carried out in Germany on millimeter-wave effects during the past 2 to 4 years. In addition, the report examines other bioelectromagnetics research related to biological effects as well as diagnostic and therapeutic applications.